2 Sheets.
Sheet 1.

H. Bessemer.

Manuf. of Iron & Steel.

No 51,401. Patented Dec 5. 1865.

Fig: 1.

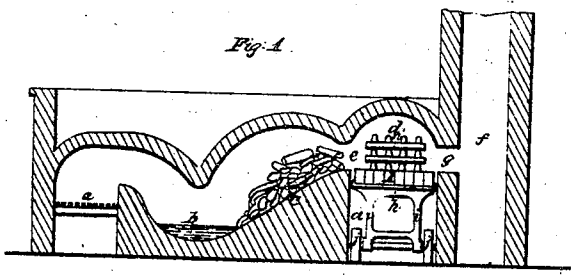


Fig: 2.

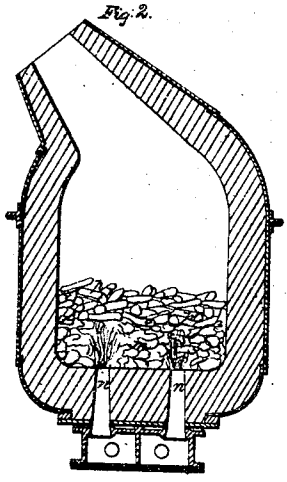


Fig: 4.

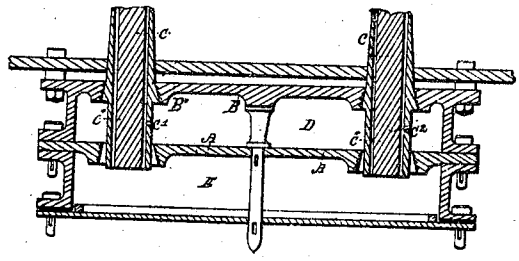


Fig: 5.

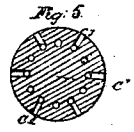


Fig: 3.

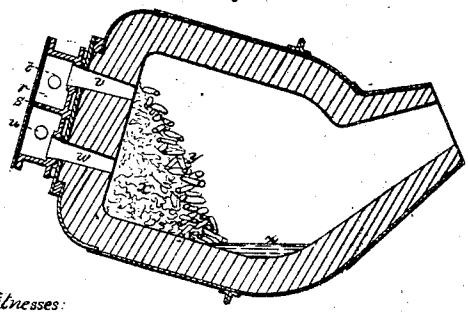
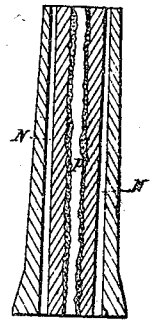


Fig: 9.



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Henry Bessemer,
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his Attys

2 Sheets.
Sheet 2.

H. Bessemer.

Manuf. of Iron & Steel.

No. 51,401. Patented Dec. 5. 1865.

Fig: 6.

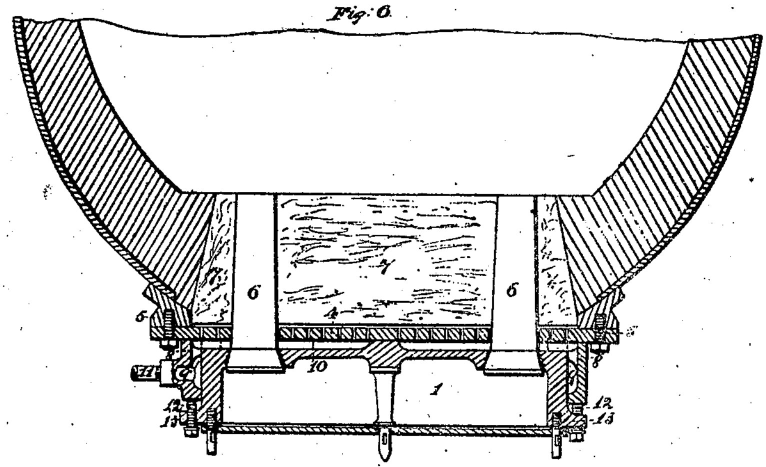


Fig: 7.

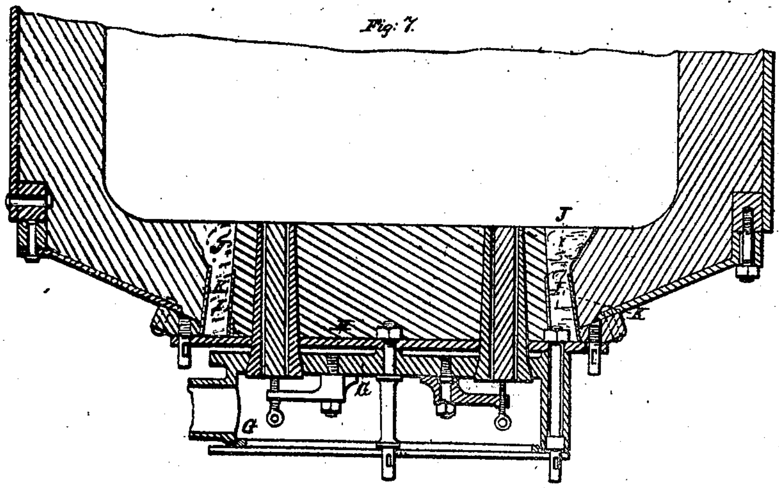
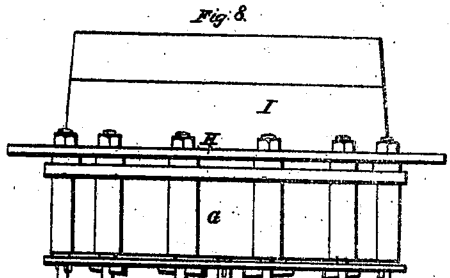


Fig: 8.



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UNITED STATES PATENT OFFICE.

HENRY BESSEMER, OF LONDON, GREAT BRITAIN.

IMPROVEMENT IN THE MANUFACTURE OF MALLEABLE IRON AND STEEL.

Specification forming part of Letters Patent No. 51,401, dated December 5, 1865.

To all whom it may concern:

Be it known that I, HENRY BESSEMER, of Queen Street Place, New Cannon street, in the city of London, England, a subject of the Queen of Great Britain, have invented or discovered new and useful Improvements in the Manufacture of Malleable Iron and Steel and in the Apparatus Employed in such Manufacture; and I do hereby declare that the following is a full, clear, and exact description thereof, reference being had to the drawings which accompany and form a part of this specification.

This invention relates to the manufacture of malleable iron and steel from pig or other carburet of iron by forcing atmospheric air into the molten metal, this method of operation being now generally known as the "Bessemer process."

When steel or malleable iron is so made from pig-iron a reverberatory furnace has generally been employed to melt the crude metal, and it has been found that a loss in the original weight of metal takes place in such melting process, and also that some of the carbon present in the iron is lost, while the proportion of sulphur it contains is augmented.

Now, therefore, the first part of my said improvements has for its object the lessening of the quantity of iron and carbon lost in the melting process, and also the lessening of the quantity of sulphur absorbed, while, at the same time, the quantity of fuel consumed in the melting-furnace is diminished.

In order to carry into practical operation this first part of my said improvements I employ a reverberatory furnace constructed in the manner usual for melting pig-iron, excepting at that end of it which is nearest the chimney, where it is provided with a second hearth or chamber having a flat or nearly-horizontal bottom, through which the flames and heated products of combustion pass on their way to the chimney. This chamber may, if desired, be a simple elongation of the bank or part on which a portion of the metal is to be melted; but I prefer to separate the melting-chamber from the second chamber by a dip in the roof, so as to contract the aperture leading from the first to the second hearth. The bed of the second hearth may, if desired, be made movable on wheels, so as to facilitate the removal of the pig-metal and convey it to the converting-vessel.

In order that this combination of a melting-furnace with a heating-chamber may be fully understood, I have given a longitudinal section of such furnace at Fig. 1 on Sheet A of the drawings hereunto annexed, where *a* is the fire-grate; *b*, the bed of the furnace, where the molten metal accumulates, and *c* the bank on which the charge of pig-iron intended to be melted is placed.

The additional heating-chamber *d* communicates with the melting-chamber by an opening at *e* and with the chimney *f* by an opening at *g*. The chamber *d* extends downward to the floor-level, so that the carriage *h* may be readily moved in and out of the heating-chamber. This carriage consists of an iron frame, *i*, mounted on four wheels, two of which are shown at *j*. The upper part of the carriage-frame is recessed for the purpose of retaining the fire-brick floor *k*, on which the metal to be heated is packed in such a manner as to admit of the passage of the heated products of combustion from the melting-chamber through or between it, as shown at *n*, whereby the metal placed on the bed *k* may be highly heated during the fusion of the other portion in the melting-chamber. A pair of folding doors or a sliding door made after the manner generally used in such furnaces will allow the carriage to be moved in and out of the furnace when required.

If it be preferred to employ a solid bottom to the heating-chamber it may be made at the same level as the bed *k*, and a smaller door may in that case be provided for the removal of the heated metal.

In this arrangement for melting and heating metal it will be understood that no more fuel will be necessary than is sufficient to melt the charge of metal on the first hearth, and also that the decarbonization and absorption of sulphur will be less in the unmelted portion of the charge than it is in the portion that has undergone fusion. From one-third to one-half the whole charge may be thus heated without being melted in the furnace; but these proportions may be varied to suit the heat-producing quality of the iron when undergoing the converting process. As soon as that portion of the metal occupying the first hearth or chamber is melted the

metal occupying the second one will have become highly heated, and may then be put into the converting-vessel while still in a solid state, and the molten part of the charge be immediately run into the vessel with it, and the converting-vessel may then be turned up and the forcing in of atmospheric air be proceeded with in the usual manner or the unmelted portion of the iron may be put into the converting-vessel after the melted portion has been run into the vessel or after it has been partially decarbonized.

When steel is required the process may be arrested at that stage where the desired amount of decarbonization has been arrived at, or the metal may be wholly or nearly decarbonized and then have mixed with it a further portion of carburet of iron in such quantity as will give to the converted metal the degree of hardness or temper required. The white pig-iron known as "Franklinite," or the white pig-iron known as "spiegeleisen," mixed with a small quantity of grey iron containing from four to five per cent. of silicium has been found most suitable for recarbonizing the converted metal, and is now generally employed for that purpose. This carbureting or alloying metal may be put into the converting-vessel in a heated and unfused state or in a melted state, as generally practiced. It will nevertheless be understood that the metal heated in the second hearth may be of the same quality as that melted on the first hearth, or it may, if desired, be of some other kind or quality of iron, either in a crude or in a refined, or partially refined, state, and although I prefer to economize fuel by heating the unmelted portion of the metal in the after part of the same furnace by means of the waste heat of such melting process, as hereinbefore described, it will nevertheless be understood that such metal may be heated in any other suitable manner, or the metal forming a portion of the charge may, if preferred, be used in less quantity without being heated at all previous to its being put into the converting-vessel. In either case the addition of sulphur thereto and the loss of carbon therefrom will be effected in a less degree than would result from the fusion of the whole charge of metal in the reverberatory furnace, as heretofore practiced.

I would here remark that in Letters Patent issued to me, No. , I have referred to a furnace in compartments for heating and converting the same metal; but important advantages will be secured by performing both these operations in the same compartment of a suitable vessel. Among these advantages are that, if desired, such vessels may be readily mounted on an axis, and the construction is also simpler and more convenient.

When it is desired to employ a carburet of iron of a cheap or inferior quality—such as is usually made from the black-band or argillaceous ores—along with the purer kinds of iron—such as are obtained from spathose or hematite ores—I prefer to melt the better quality of iron in a reverberatory furnace, as heretofore generally practiced, except in those cases where such fluid iron from blast-furnaces can be conveniently obtained, and the inferior or cheaper kinds of pig-iron to be mixed therewith I first subject to a refining process by any of the methods now in use for refining crude iron, or such inferior or cheaper quality of iron may be purified and refined by puddling it more or less, so that it may be brought nearly or quite to the point at which the process is generally stopped when making puddled steel, or it may be carried to the extent usual when making wrought or malleable iron. This puddling or partial puddling of the metal prior to its mixture with a carburet of iron in the converting-vessel may be performed by any known mode of puddling mechanically or it may be simply effected by hand-labor in the usual way. In either case the metal thus purified or refined is to be put, while in a heated state, into the converting-vessel, and the rest of the charge, consisting of the molten carburet of iron, is then to be run in with it, and the process of conversion by air proceeded with in the same manner as hereinbefore described. When heated pig-iron is employed in a solid state along with the fluid metal.

In carrying into practical operation this part of my said invention the inferior or cheaper kinds of iron—such as are produced from the black-band iron-stone or from argillaceous and other ores of iron—may be employed in combination with other and purer carburets of iron in the production of steel or malleable iron of a quality for which such cheap or inferior iron is not so well adapted in its unrefined state; and although the puddling or partial puddling of such cheap or inferior kinds of iron may be performed by manual labor in the ordinary way it will be obvious that the metal may be more cheaply and advantageously refined in large quantities by some of the well-known arrangements of mechanical puddling apparatus in which that process is effected in a revolving cylinder or otherwise. I prefer that the metal should be carried to about that stage of the puddling process at which it has the general properties of steel, or it may, if preferred, be carried on until its complete decarbonization is effected. In either case it may be roughly balled up for convenience of removal while still in a heated state to the converting-vessel, or it may, if preferred, be mixed with the molten iron in a loose granular state, without balling it up.

The molten crude iron which I prefer to employ in combination with the puddled metal is highly carbureted, being of the quality known as "No. 1," since this quality of metal will furnish sufficient heat to melt down a considerable quantity of the puddled metal, especially if the latter be not entirely decarbonized and is put into the converting-vessel in a highly-heated state. From one-fourth to one-half,

more or less, of the puddled metal may be employed, at the discretion of the manufacturer; but this may be much varied.

The converting-vessels mounted on axes, such as are now generally employed for converting crude molten iron into steel or into malleable iron by the Bessemer process, are generally heated to a very high temperature previous to running the fluid metal therein, and it has been the general practice to continue the combustion of fuel in the vessel during the whole or a great part of the time occupied in melting the charge of pig-iron in a reverberatory furnace, which is intended to be converted therein.

Now, the object of the second part of my said improvements is to economize the fuel so used and at the same time to lessen the wear and tear of furnaces by employing the converting-vessel as a heating or melting vessel, wherein the metal to be converted may be highly heated while in the solid state or be wholly or in part melted therein, and be, without removal from the vessel, at once converted into malleable iron or steel. When solid fuel is to be employed for this purpose a fire may be lighted in the converting-vessel and a moderate blast may be employed until it is well ignited. The carburet of iron, whether in the state of pig-iron or refined in any way, is to be thrown upon the fuel and the blast then urged until the metal is very highly heated.

This mode of heating the metal may be readily understood by reference to Sheet A of the annexed drawings, where Fig. 2 is a vertical section of a converting-vessel, such as is now generally employed in the manufacture of steel by the Bessemer process, and such as has been described in my previous patents.

It will be perceived that the fuel *m*, lying over the numerous orifices of the tuyeres *n*, will be highly ignited by the powerful blast issuing from them, and consequently the lumps of metal *p* will acquire a very high temperature by the time the vessel has been sufficiently heated.

It is desirable to use no more fuel than will suffice by its combustion to heat the vessel and the metal sufficiently, or there may be some difficulty in removing the unconsumed fuel which floats on the surface of the metal which is afterward put in.

When the metal is sufficiently heated the vessel is then to be turned into a position to receive some molten carburet of iron, which may then be run in from any suitable melting-furnace, blast-furnace, or ladle. When this is done any fuel still remaining unconsumed may be raked out at the mouth of the vessel, which may then be turned up, and the process of decarbonization at once commenced by forcing upward through the fluid metal atmospheric air or other gaseous matter capable of decarbonizing and raising the temperature of the metal.

When treating crude or pig iron which is highly carbonized the heating of it in the converting-vessel may be proceeded with until the sparks thrown out of the mouth of the vessel indicate the commencement of fusion. At this stage of the process the vessel may be partly turned down, so that the drops of fused metal will not accumulate over the orifices of the tuyeres, but will occupy the same part of the vessel which a charge of iron usually occupies when first run into the vessel. This position of the vessel and its contents is shown in vertical section at Fig. 3 on the annexed Sheet A of drawings. In order to effect this fusion of the metal without any undue oxidation thereof, I prefer to divide the tuyere-box or make separate tuyere-boxes, so that the blast of air employed to urge the fire may be conveyed only from those tuyeres that are below the fuel when the vessel is partly turned down, as before described.

I may here remark that separate and divided tuyere-boxes have been shown in previous patents of mine, but were there shown as used for a different purpose.

In Fig. 3 of Sheet A of the drawings annexed the tuyere-box *r* is shown with a division-plate, *s*, formed therein, so that the blast of air may be admitted to each compartment of the tuyere-box when necessary by pipes communicating with it at *t* and *u*; but when the fusion of the metal commences the vessel should be turned on its axis until it assumes the position shown in Fig. 3, and the supply of air should then be turned off by a suitable valve from the pipe *t*, and consequently be prevented from passing through the tuyeres *v*, where there would be little or no fuel for it to act upon. The communication with the blast-engine is, however, still to be kept up by means of the pipe *u*, which enters the lower part of the tuyere-box and admits a powerful blast through the lower set of tuyeres *w*, and will act on the fuel which will have fallen in front of these tuyeres somewhat into the position shown at *x*. The flame thus produced will rapidly bring about the fusion of a part or the whole of the charge of metal shown at *y*, the fused portion of which is also shown accumulating at *z*, where it will be still subjected to the action of the flame and heated products of combustion, and its temperature be thus kept up, although it is at too low a level to use above the orifices of the tuyeres.

As soon as the whole or a sufficient quantity of the charge of iron is melted I prefer to remove as much as possible of the unconsumed fuel, which will be found floating on the surface of the fluid metal and nearly on a level with the mouth of the vessel. The fuel may be raked forward and allowed to fall out onto the floor of the casting-pit, and if the blast be turned on at full pressure from the upper set of tuyeres while the vessel is still in the position shown in Fig. 3, any remaining portions of the fuel will be blown out of the mouth of the vessel, after which the vessel may be turned up and the conversion of the metal effected by forcing atmospheric air

into and below the surface thereof, as now generally practiced, the charge of metal so treated being composed wholly of pig or refined iron; or it may be composed partly of crude pig or other carburet of iron and partly of iron which has been more or less refined by any known or adequate process previous to its being put into the converting-vessel.

The fusion of the metal may be effected by coke as much freed from sulphur as possible, or any purer fuel capable of giving sufficient heat may be employed in lieu thereof.

When convenient the gases from the blast-furnaces may be employed, or carbonic oxide or carbureted hydrogen or mixtures thereof may be employed to heat or melt the metals in the converting-vessel, in order to prepare such metal for conversion. I prefer to convey jets of combustible gases and atmospheric air into the vessel through the tuyeres for the purpose of heating or melting in the converting-vessel a portion or the whole of the metal that is to be converted therein; but these jets may be conveyed through tuyeres placed elsewhere.

I prefer to make a division of the tuyere box or boxes in such a manner as will admit of streams of air and streams of gas being directed into the vessel through the tuyeres, or the air and gases may be conveyed into the vessel through separate tuyeres and tuyere-boxes, so as to cause a complete combustion of the gases, but which shall nevertheless be capable of such regulation as will prevent any undue loss of metal from oxidation.

Both the air and gases may, if desired, be employed in a heated state, and when thus applying gases through the tuyeres separate communication may be made for them through the axes of the vessel, or a temporary communication may be established by a movable pipe or connection with a gasometer.

In order that this mode of heating or melting metal by gas in the converting-vessel prior to the conversion of such metal may be fully understood, I have shown at Fig. 4 of Sheet A of the annexed drawings a vertical section of a tuyere-box having a division-plate, A, therein, as before referred to. This plate is provided with a series of conical openings which are placed opposite to a similar set of openings formed in the upper part, B, of the tuyere-box B. The tuyeres C have an elongated part at C, which passes through the openings in the plate A, and is kept air-tight therein by ramming some clay into the joint around the lower end of the tuyere. Every alternate hole in the tuyere should have another hole C′ made in it at right angles to the main passage which passes longitudinally through it, the bottom ends of each such passage being plugged with clay, whereby all such passages through the tuyere may be made to convey gas from the upper or gas chamber D of the tuyere-box into the vessel, but can convey no air from the lower or air chamber, E, in consequence of the lower ends of such passages being plugged, while all those longitudinal passages in the tuyere which have no cross-passage communicating with the upper or gas chamber, D, and are open at their lower ends will convey atmospheric air into the vessel. By this arrangement each tuyere will somewhat resemble an Argand gas-burner with air and gas issuing from alternate holes around its outer edge. A horizontal section of such a tuyere is shown at Fig. 5.

This mode of supplying air and gas in separate streams through the tuyeres into the vessel will produce an intense combustion and rapidly heat or melt the metal therein, the quantity of air and gas supplied for this purpose being regulated by valves on their respective supply-pipes, as well as by the amount of pressure under which the air and gas are supplied.

My improvements relate, thirdly, to a mode of setting tuyeres in converting-vessels employed in the manufacture of malleable iron and steel. As now generally practiced, the tuyeres project upward from the tuyere-box into the vessel, and the spaces between them are filled up with a mixture of powdered ganister and water having the consistency of batter. As much as fifteen or twenty gallons are sometimes used, and it has been found to occupy an inconvenient amount of time and expenditure of fuel to evaporate the water from this semi-fluid matter. I therefore perforate the lower plate of the converting-vessel and put on it felt or some woven fabric capable of allowing the water to drain through; or, if the perforations in the plate are very small, the water will drain through the plate without the addition of any other porous substance. I prefer to assist the extraction of the water by means of a partial vacuum formed by an exhaust-pump connected with the under side of the perforated plate, an air-tight joint around the upper part of the tuyere-box being made by a turned ring of metal or by india-rubber or other suitable packing. A small exhausting-pump may be connected to the tuyere-box by a movable pipe or the blast-engine employed to force air into the metal may have the valves so arranged as to render it capable of acting at any time as an exhaust-pump. In either case a receiver should be placed on the exhaust-pipe into which the water would flow instead of going into the exhaust-pump; and although I have explained how the drying of the material occupying the spaces between the tuyeres may be facilitated by drawing off a large portion of the water therefrom, I nevertheless desire it to be understood that this application of the exhaust-pump enables me to use a nearly or perfectly dry material, such as coarse sand, ganister, or other refractory material in a state of powder, the pressure of air on the upper surface of the mass holding it firmly in place until the heat and slags have sufficiently consolidated its surface, and by this means the setting of tuyeres will be greatly expedited.

It has hitherto been the general practice to so connect the tuyere-box to the converting-

vessel as to leave a space between them for the free escape of air should any portion leak out by the side of the tuyeres, a provision which it is important to retain. When, therefore, it is intended to apply the principle of exhaustion to the removal of water from the semi-fluid materials run in between the tuyeres, I so arrange the closing up of this space that when the drawing off of the water has been effected the space for the escape of air from leakage may again be readily opened. The mode by which I effect this object will be better understood by reference to Sheet B of the drawings hereto annexed, where Fig. 6 is a vertical section through the tuyere-box and a portion of the lower part of the converting-vessel. 1 is the tuyere-box secured by studs 5 to the lower part of the converting-vessel. These studs pass through the plate 4. This plate is secured to the tuyere-box at several places by bolts. The plate 4 is perforated and has upon it a piece of felt or wire-gauze or other pervious woven fabric, in which holes are cut for the tuyeres 6 to pass through, and which will prevent the solid particles of ganister or sand from passing through the perforations in the plate 4, although it will allow the passage of water from the semi-fluid mass which is shown at 7, and which fills the spaces between and around the tuyeres. The outside of the tuyere-box is turned truly to fit the inside of the ring of metal 8. The upper part of this ring is made true, or it may be covered with some elastic material, so as to make a nearly close or air-tight joint with the plate 4. There are vertical ribs at intervals formed around the inside of the upper part of the ring 8, so as to guide it up and down steadily on the outside of the tuyere-box. These ribs do not obstruct the communication between the space 10 and the annular space 9 which surrounds the tuyere-box, and into which a pipe, 11, is fitted. This pipe may be unscrewed so soon as the withdrawal of the water is effected. The ring 8, when in use, is forced upward in contact with the plate 4 by several screws, 12, which pass through lugs 13, cast on the tuyere-box. The withdrawal of these screws will allow the ring 8 to sink down onto the lugs 13 and again open the space 10, so that any air that may leak from the tuyere-box around the tuyeres may escape freely.

The loss of time occasioned by the drying of tuyeres set in the manner herein first described will be for the most part prevented by providing several tuyere-boxes or tuyere-plates through which the tuyeres project. A raised conical ring may be placed around them, and the spaces between the tuyeres rammed up with ground ganister or other material and then baked dry. The ring may be then removed, and in that dry state they may be put into the vessel. I prefer that a hoop of iron or a ring of brick-work should be placed around the lower part of the vessel for the purpose of defining the size of the opening left by the removal of a set of worn-out tuyeres. I also prefer to make this opening of such a size as will admit the set of dried tuyeres very freely, and leave a space of one or two inches around them, which may be filled with ganister mixed with water run in from the top, or preferably from an opening on the outside of the vessel, or the space may be filled with dry sand or other material.

This mode of building up and baking a set of tuyeres in a tuyere-box previous to putting them into the converting-vessel will be better understood by reference to sheet B of the drawings hereunto annexed, which shows the methed I prefer for carrying out this part of my invention.

Fig. 7 is a section of a tuyere-box and the lower part of the converting-vessel. The tuyere-box with the tuyeres built up and ready for inserting into the vessel is shown in elevation at Fig. 8.

The tuyere-box G is, as usual, provided with a plate, H, with an interval for the escape of air in case of leakage. To the plate H a conical ring of thin iron, I, is fixed, which serves to retain the material which occupies the space between and around the tuyeres. This material, which consists generally of ground ganister moistened with water, is to be rammed into the space included within the ring I, and is also to be carried up at the same angle as high as the top end of the tuyeres, and it may then be slowly dried or baked. When inserted in the lower part of the vessel a space, J, will be left, which is to be filled with a semi-liquid mixture of ganister and water, which may be run in in the way generally practiced when setting tuyeres. The water from this small portion will be soon absorbed by the dry surrounding materials, and the vessel will thus, in a short time, be in a condition suitable for the converting process. When worn out the whole mass shown in Fig. 8 can be removed. The conical ring K (shown in section at Fig. 7, and which is bolted to the lower part of the vessel) will determine the line of separation of the materials when the tuyere-box is removed. I, however, desire it to be understood that I do not claim the removal of the whole bottom of the vessel with the tuyeres therein, because this has already been practiced.

The tuyeres used in the manner hereinbefore described sometimes break transversely and the air, by getting into the crack, forces the upper end of the tuyere into the metal and causes the lower part of the tuyere to quickly wear away. To prevent this I make a somewhat larger hole in the center of the tuyere, roughened or corrugated throughout its length, and into this I insert an iron bolt or rod, also roughened or formed with rings on its surface. I then pour some cement into the space formed between it and the inside of the tuyere-holes, so that the tuyere may be effectually held in place even if a fracture should take place. A longitudinal section of a tuyere so constructed

is shown at Fig. 9 on Sheet A of the annexed drawings, where N N show the air-passages and P the corrugated or ribbed iron rod or bolt put into the corrugated central opening, and then run in with a mixture of Portland cement and ground fire-brick, or with other suitable cement.

In the manufacture of malleable iron and steel from crude iron or from refined or partially-refined iron by forcing atmospheric air into and below the surface of the fluid metal, the air has hitherto been simply conveyed from the blast-engine or air-vessel in a cold or in a heated state directly into the converting-vessel without otherwise altering the properties or gaseous constituents of the air so employed, excepting in those cases where steam has been mixed therewith; but I have found that the molten iron and the substances incorporated therewith may be acted upon more or less advantageously by charging or impregnating the air with the vapors of acids, alkaline, or saline fluids or hydrocarbons, or by passing the air through or between any solid substances capable of vaporizing or in part vaporizing or altering the properties of the air with a view to act upon or combine with the substances present in the crude metal, and thus further refine, purify, or improve its quality. The air and the fluid or solid substances among which it is passed may be either in a cold or in a heated state, as may be found preferable.

In carrying this system into practical operation I prefer to line the lower part of the air-receiver, which is in communication with the blast-engine, with lead or with pottery-ware, or with other substances not easily destroyed by the fluids to be employed therein, the air from the blast-engine being conveyed through perforations situated below the surface of such fluid, and being allowed to bubble up through it, and thus become more or less altered in its properties and chemical constituents prior to its passage through the tuyeres into the molten metal.

I desire it to be understood that I do not claim as my invention the employment of any special fluid matters through which the air is to be passed or to become impregnated with, as the same will depend on the nature of the substance contained in the iron which it is intended to act upon, or whether such alteration of the constituents of the air is effected for the purpose of increasing the temperature of the contents of the converting-vessel, or for so combining with the oxygen contained therein as better to adapt the air for use, as a means of mixing or agitating the fluid metal after conversion or otherwise.

But having described the several parts of my said invention and the manner in which the same may be carried into practical operation, I desire it to be understood that I do not confine myself to the precise details herein given, provided the essential parts of my said improvements be retained; but

What I claim in the manufacture of malleable iron and steel and in the apparatus employed in such manufacture is—

1. In the manufacture of malleable iron and steel, the employment, in the converting-vessel, of a portion of the charge of pig or refined iron in a solid and unmelted state when placed to be heated and converted in the same compartment of such vessel in combination with another portion of crude iron in a fluid state, in the manner and for the purposes described.

2. In the manufacture of malleable iron and steel, the employment, in any suitable vessel, of a portion of the charge of pig or refined iron in a solid and unheated state in combination with another portion of crude iron in a fluid state, substantially in the manner and for the purposes described.

3. The manufacture of cast-steel and cast malleable iron by mixing and combining molten carburet of iron with other iron or steel which has been refined or partially refined by puddling, but which has not been manufactured into finished steel, where the fusion of such refined or partially-refined iron or steel is effected by forcing atmospheric air or other gaseous matters into the said molten carburet of iron.

4. Heating or melting iron in the converting-vessel by heat derived from the fuel employed preparatory to the commencement of the converting process for heating or drying such vessel.

5. The application to the heating or melting of iron in the converting-vessel either by solid or gaseous fuel of the same apparatus which forces or conducts air or gases into such vessel for the purpose of carrying on the converting process therein.

6. Constructing a tuyere-box in such a manner that the air may at will be admitted to or excluded from one or more of the tuyeres, substantially as and for the purposes described.

7. Converting iron in a suitable vessel by means of carrying air or other gases through suitable apertures into such vessel for the purpose of heating or melting the iron therein, in combination with carrying air or other gases by suitable apertures among the particles of said iron, for the purpose of effecting the conversion thereof.

8. Combining with a converting-vessel a perforated plate, either covered or not covered with a suitable porous fabric or its equivalent, substantially as and for the purposes specified.

9. The mode herein described of securing the tuyeres to the tuyere-box.

10. Using the ring K of any suitable material or its equivalent for the purpose of defining the size of the opening of the line of fracture in that part of the converting-vessel where the tuyeres are inserted, substantially as described.

11. Setting one or more tuyeres in a mass of ganister or other suitable material in such manner that they may be attached to or removed

from a converting-vessel without taking off the bottom of such vessel, substantially as and for the purposes described.

12. The employment of a partial vacuum for drying or consolidating the materials employed in setting tuyeres in converting-vessels.

13. The mode, substantially as described, of strengthening a tuyere by a central iron rod, and thus holding the parts thereof together when fractured.

14. In the manufacture of malleable iron and steel, passing the atmospheric air to be employed in the conversion through and in contact with acid or alkaline solutions or hydrocarbons prior to the passage of such air into the converting-vessel.

HENRY BESSEMER.

Witnesses:

THOS. BROWN,

DAVD. LONGSDON.