

# Henry Bessemer of London, England - US Patent #16,082, Nov. 11, 1856 "Manufacture of Iron and Steel"

Skyscraper Inquiry Unit

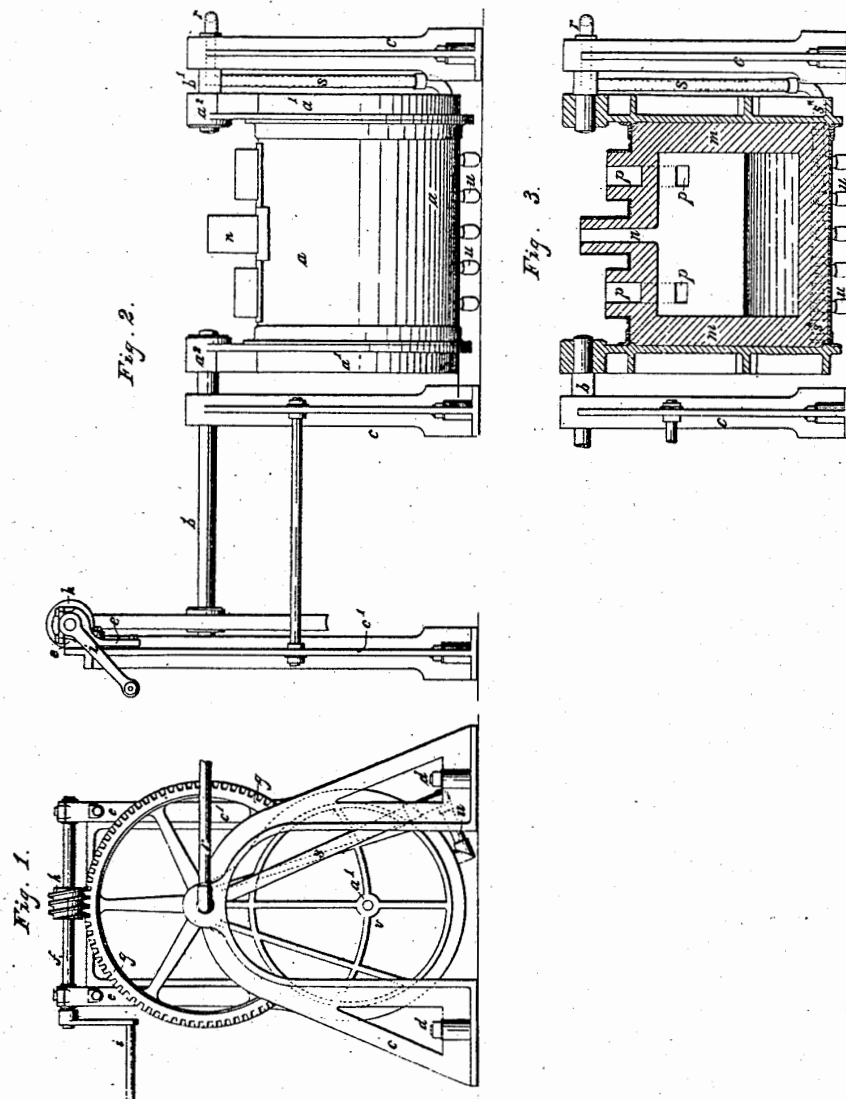
\*Note: US inventor William Kelly appealed this patent to the patent commissioner claiming he had devised this process years earlier, although he had not filed for a patent. Kelly's appeal was successful. Kelly obtained his patent in 1857. (See William Kelly, US Patent 17,628 June 23, 1857 in the REACH Primary Source Documents) Significant debate ensues about this topic. Often referred to as the Bessemer-Kelly Process, though the process was further enhanced with additional improvements and developments.

4 Sheets—Sheet 1.

## H. BESSEMER. MANUFACTURE OF IRON AND STEEL.

No. 16,082.

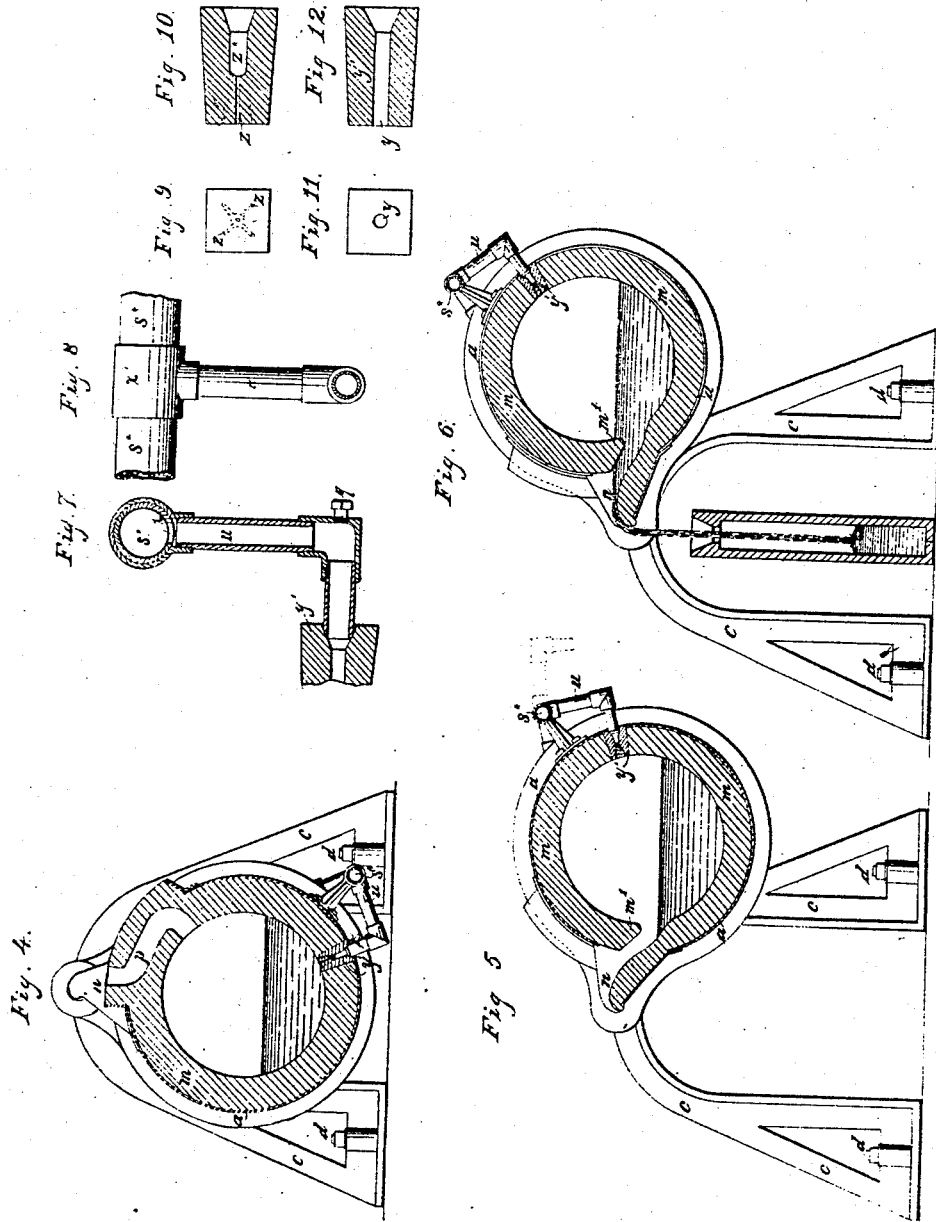
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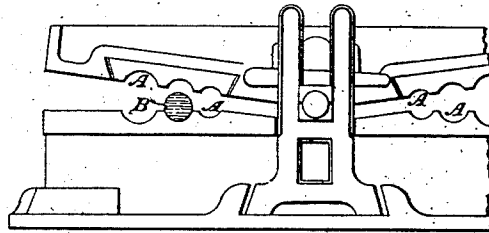


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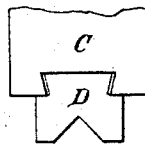
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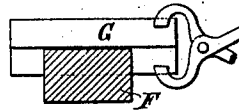
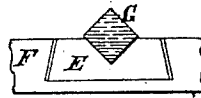
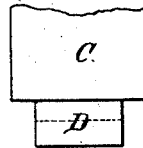
*Fig. 1.*



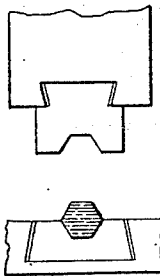
*Fig. 2.*



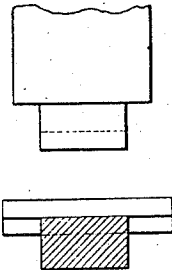
*Fig. 3.*



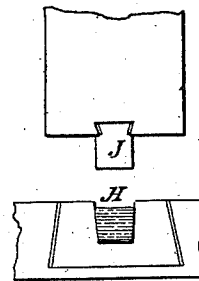
*Fig. 4.*



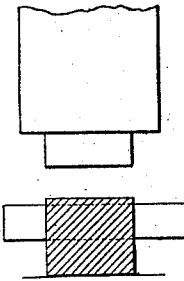
*Fig. 5.*



*Fig. 6.*



*Fig. 7.*

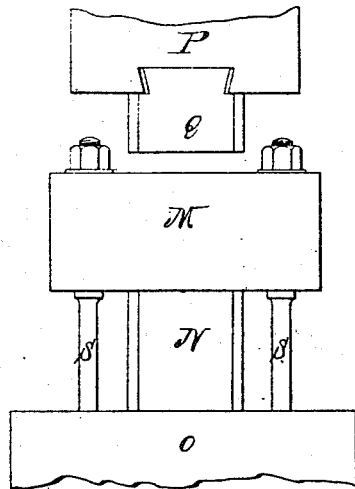


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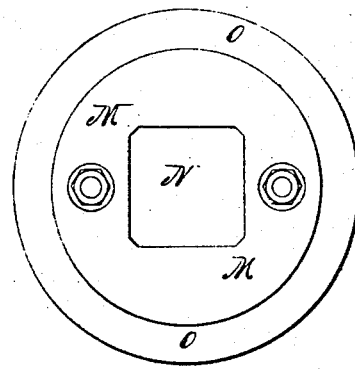
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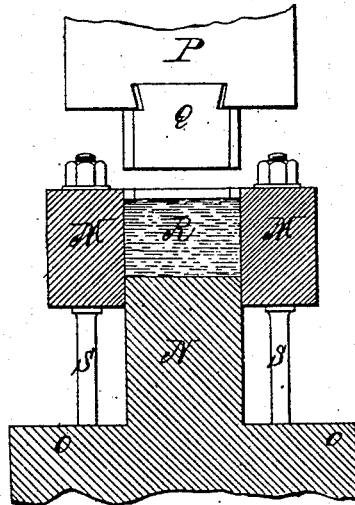
*Fig. 8.*



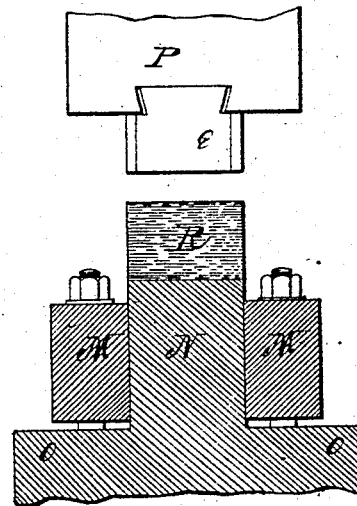
*Fig. 9.*



*Fig. 10.*



*Fig. 11.*



# UNITED STATES PATENT OFFICE.

HENRY BESSEMER, OF LONDON, ENGLAND.

## IMPROVEMENT IN THE MANUFACTURE OF IRON AND STEEL.

Specification forming part of Letters Patent No. 16,082, dated November 11, 1856.

*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, civil engineer, a subject of the Queen of Great Britain, have invented or discovered new and useful Improvements in the Manufacture of Malleable or Bar Iron and Steel; and I, the said HENRY BESSEMER, do hereby declare the nature of the said invention and in what manner the same is to be performed to be particularly described and ascertained in and by the following statement thereof—that is to say:

My invention consists in the decarbonization or partial decarbonization and refinement of the crude iron which is obtained in a fluid state from the blast-furnaces in which the iron ore is usually smelted, or the decarbonization and refinement of crude pig-iron or finery iron, by first smelting the pigs of crude iron or the plates of finery iron in any suitable furnace, so as to obtain fluid metal for the purpose of being treated by my improved means; and which consists, first, in running the fluid iron into a close or nearly close vessel or chamber, formed by preference of iron, and lined with fire-bricks or other slow conductor of heat. When the chamber or vessel is about filled, I blow or force into and among the fluid metal numerous small jets of atmospheric air in a cold or in a previously-heated state, or I use any other gaseous fluid or matter containing or capable of evolving sufficient oxygen to cause the combustion of the carbon contained in the iron, and thereby to keep up the required temperature during the process. The size or number of the jets or tuyere-pipes by which the air or other gaseous matters are conducted into the molten metal should be proportioned to the quantity of fluid metal operated upon at a time, and may also vary with the condition or quality of the metal. Thus forged pig or refined plate metal will not require so much oxygen to complete its decarbonization and conversion into steel or malleable iron as is required for the conversion of crude iron of the qualities known as "No. 1" or "No. 2" foundry-iron, to which last-named qualities of iron I prefer to use tuyeres having an outlet of about twenty per cent. more in area than those which are used for the white qualities of iron. It is, however, difficult to

give a precise or fixed rule for the size of the jets or tuyere-pipes, because the quantity of air passing through them depends so much on the force or pressure of the blast. The quantity should depend also on the quality of the iron and the heat of the air or other gaseous matters used with the air, or in lieu thereof; but as a guide to the workman, I will give an example which I have found in practice to answer well: When using foundry-iron of the quality known as "No. 2," I run one ton of it into the converting-vessel, in which it rises to a height of about one foot above the orifices of the tuyere-pipes. I then force into the fluid metal atmospheric air, in its natural or unheated state, under a pressure of about ten pounds per square inch, and I employ from six to twelve tuyere-pipes for the distribution of the air; the united area of the tuyeres being equal to two square inches. The quantity of blast admitted by this area of inlet will in general be found sufficient to effect the conversion of the crude iron into a malleable condition in about thirty minutes; but should it be preferred to use a mixture of oxygen gas with atmospheric air or steam, or to use steam alone or any other gaseous fluid capable of evolving oxygen in lieu of atmospheric air, then the size of the tuyere-pipes should be regulated according to the quantity of oxygen contained in such gaseous fluids. Any excess of oxygen over that usually contained in atmospheric air will admit of a diminution of the tuyere-pipes, while a deficiency of oxygen will render necessary a corresponding increase in the size of the tuyeres.

The interior of the vessel may in some cases be heated by the waste gases of the blast-furnace or by any other convenient means, previous to the crude iron being poured or run therein; but this heating up of the vessel will only be necessary at such times as the vessel is used with a new lining, which should be well dried, or at such other times as the vessel may be used after the process has for several hours been discontinued, in which case I prefer to reheat the vessel, although the process may be conducted successfully in a vessel that is perfectly cold previous to the running in of the molten iron. Now, it is well known that molten crude iron, under ordinary circumstances, will soon become solidi-

ied unless a powerful fire is kept up and is applied direct to the fluid metal or to the exterior of the vessel containing it. It is also well known that if the quantity of carbon which is usually associated with crude iron is diminished, the temperature necessary to maintain its fluidity also rises in like manner, so that when the iron has lost the whole or the greater part of its combined carbon, such metal can only be kept in a fluid state by the heat of the most powerful furnaces; but I have discovered that if atmospheric air or oxygen is thus introduced into the metal in sufficient quantities, it will produce a vivid combustion among the particles of fluid metal, and retain or increase its temperature to such a degree that the metal will continue fluid during its transition from the state of crude iron to that of cast-steel or malleable iron without the application of any fuel; the requisite high temperature of the metal by such mode of action being obtained by the oxygen uniting with and causing a combustion of the carbon contained in the crude iron, and also by the combustion of a small portion of the iron itself. In carrying my invention into practical operation, I prefer to mount the refining vessel or chamber on axes not situated at or near the center of gravity of the said chamber, by which means the pouring out of its contents will be facilitated, and the spout kept in a proper position in reference to the mold during the time of pouring the fluid metal therein. The air may be introduced at the sides or ends of the vessel through small holes formed in pieces of well-burned fire-clay, so that by moving the chamber or vessel on its axes the holes in the fire-clay may be made to descend beneath the surface of the metal or be raised above it, as desired. It must be observed that the air or other gaseous matters must be compressed with a force greater than will balance the weight of a column of fluid metal of a height equal to the depth of immersion of the jets below the surface of the fluid metal.

In order that this particular form of apparatus may be fully understood, I have hereunto annexed a sheet of drawings (marked A) on which the same is represented, Figure 1 being an end elevation thereof; Fig. 2, a longitudinal elevation, and Fig. 3 a longitudinal section, of the vessel or chamber; and Figs. 4, 5, and 6 are cross-sections of the same in different positions. The tuyere-pipes are also shown in detail on a larger scale at Figs. 7, 8, 9, 10, 11, and 12. The cylindrical vessel *a* is formed of stout plate-iron, secured by angle-iron flanges to the cast-iron end plates, *a'*, on which ribs or webs are formed for the purpose of giving to them the requisite degree of strength. At one side of the plates *a'*, and at a point beyond their outer edges the bosses *a''* are formed. They are bored out truly, and fitted and keyed to the axes *b* and *b'*, on which the converting-vessel *a* is made to move when required. *c c* are iron frames, secured by bolts *d* to the ma-

sonry or foundation on which the whole apparatus rests. The frame *c'* rises higher than the others, and has plumper-blocks *e e* bolted to it, in which the shaft *f* revolves. A worm-wheel, *g*, is keyed firmly onto the axis *b* and receives motion from the worm *h* whenever the handle *i* and shaft *f* are moved round. The interior of the vessel *a* is lined with fire-bricks or fire-stone, as shown at *m*; or it may be lined with any other slow conductor of heat capable of withstanding the high temperature and solvent action of the slags to which the lining is exposed when the vessel is in use. The bricks or fire-stone may, however, be protected and mended or patched from time to time by a coating of loam, road drift, iron-ore slags, or such other matters as are commonly employed for mending and protecting the walls of furnaces used in the manufacture of iron. The lining may be renewed from time to time, when worn out, by removing either of the end plates, *a'*, which may again be bolted onto the vessel as soon as the new lining is completed; or a man-hole (not shown in the drawings) may be made in one side of the vessel, through which the lining or repairs may be effected without removing the end of the vessel. At *n* there is formed a projecting spout or lip for the purpose of running out the fluid metal. This lip is made to project from the vessel so far as to bring it in a line with the axis, so that into whatever position the vessel *a* may be moved the extremity of the lip *n* may retain the same position or nearly so, and thus allow the stream of metal flowing over it to fall into the ingot-mold, which would not be the case if the axis were placed in a line with the center of the cylindrical vessel. By reference to Fig. 6 it will be seen that at *m'* the lining is formed so as to prevent the metal from carrying out with it the slags or other matters floating on its surface until after the metal has run out.

On each side of the spout *n* there is a *c* passage, *p*, by means of which the flame and gaseous products evolved during the process may escape, but the splashes of metal thrown up by the jets of air are for the most part prevented from escaping from the vessel by the serpentine form of these outlets.

At *r* there is a pipe which is made to communicate with a blast-engine or with a steam-boiler; or it may be made to communicate with a reservoir containing oxygen gas, or a mixture of oxygen with other gaseous fluids, or with any gaseous matter capable of evolving oxygen, any or all of which gaseous fluids may be used for the purpose of my invention, either in a cold or heated state, although I prefer to use atmospheric air at its natural temperature on account of its cheapness and efficiency. The pipe *r* is fitted at one end to the trunnion or axis *b'*, which is made hollow, and is provided with a stuffing-box or other joint, so as to allow the movement of the axis, without interfering with the passage of the air or other matters through it. The pipe *s* is also con-

ned to the hollow axis  $b'$ , and has a right-angled elbow or bend at its opposite end, and then continues along the outside of the vessel throughout its whole length. That portion of the pipe is marked  $s^*$ , and is turned truly on its exterior surface, and has fitted upon it several small branch pipes,  $u$ , each of which has a T-piece,  $x'$ , connected to them, which is bored out truly, and made to fit accurately to the exterior of the pipe  $s^*$ , so as to admit of the pipe  $u$  being moved on the pipe  $s^*$  into the position shown by dots in Fig. 5. Along one side of the converting-vessel there is a row of square holes, into which small blocks  $y'$  of well-burned fire-clay are loosely fitted. They are held in position by ramming a little loam well into the joint formed between them and the lining  $m$ . At one end of these blocks or tuyeres the pipe  $u$  is fitted by a simple cone-joint. The other ends of the tuyere-blocks have several small holes made in them leading into one larger passage which communicates with the pipe  $u$ , so that a communication is thus established between numerous points of the interior surface of the converting-vessel and the blast-engine or reservoir of gaseous matters before referred to, and by means of which numerous small jets or currents of air or other gaseous fluids may be forced into the converting-vessel when required, a sluice-cock on the pipe  $r$  (not shown in the drawings) enabling the workman to turn off the supply of air when required. In order that the way in which the pipe  $s^*$  and the pipes  $u$  are arranged may be better understood, I have shown detached views of them at Figs. 7 and 8, where it will be seen that the pipe  $s^*$  has a hole in it at  $x$ , which is opposite the orifice of the pipe  $u$ . Through this hole the air may pass freely when the pipes  $u$  occupy their ordinary positions; but whenever any of the tuyere-blocks require renewing the pipe  $u$  can be turned up on the joint formed at its union with the pipe  $s^*$ , as shown by dots in Fig. 5, and in which position the hole  $x$  in the pipe  $s^*$  will be closed while free access to the tuyere is obtained.

I have also shown at Fig. 9 an end view, and at Fig. 10 a longitudinal section, of a tuyere-block, where  $z$  show the small apertures through which the air escapes into the metal, all of which, in passages, unite in the larger one  $z^*$ , the orifice of which is made conical, so as to fit the end of the pipes  $u$ . I have also found that a single outlet in each tuyere-block will answer well in practice, as represented in end elevation at Fig. 11, and in longitudinal section at Fig. 12, where a single parallel passage,  $y$ , leads direct from the pipe  $u$  into the metal, as these passages sometimes get obstructed. I fit a screw-plug,  $g$ , at the back of the elbow of the pipe  $u$ , which plug may be removed, if required, while the apparatus is in use, and a steel rod introduced at the aperture, which should be thrust entirely through the tuyere-block, and any accidental accumulation of matter will be thus removed.

By reference to Fig. 1 of the annexed draw-

ings it will be seen that a boss,  $v$ , is formed at the point of junction of two of the webs, which are formed on the end plates,  $a'$ , of the converting-vessel. Into this boss a stud may be fixed, to which a chain or tension-rod may be attached, for the purpose of suspending a counterbalance-weight, the chain passing over a pulley supported by the roof or other convenient part of the building, so that the vessel  $a$  may be more easily moved on its axis by means of the worm-wheel gearing before described.

Having thus pointed out the manner in which the converting-vessel and the apparatus connected therewith is constructed, I will proceed to describe in what manner the conversion of molten, crude, or finery iron is to be effected therein. I however wish it to be distinctly understood that although I prefer to use the above apparatus for the purpose of carrying out my said invention, other forms or modifications of the converting-vessel may be used with more or less advantage, and that the same may either be made movable or it may be fixed.

The apparatus should, by preference, be placed near to the discharge-hole of the blast or remelting furnace from which the crude fluid iron is obtained. The interior of the converting-vessel may be heated by burning gases therein, in a manner well understood; or some wood charcoal or coke may be introduced at the passages  $p$ , and a blast of air turned on through the tuyeres, by which the combustion of these substances may be kept up. When the fuel is consumed and the vessel dried, the air or other gaseous matters may still continue to be forced in during the time that the crude-iron is running from the smelting-furnace into the vessel. For this purpose the vessel is put in the position shown in Fig. 4, a movable gutter leading from the tap-hole of the smelting-furnace into the upper end of one of the passages,  $p$ . The charge of metal will vary according to the size of the apparatus; but I prefer, as a general rule, that the vessel should be a little less than half filled with metal. As soon as the metal begins to accumulate above the orifices of the tuyere-blocks, a violent ebullition will be produced, the air dividing into globules and diffusing itself among the particles of fluid iron, and thus coming in contact at numerous points with the carbon contained in the crude-iron, and producing thereby a vivid combustion, while the flame and gaseous products resulting therefrom make their escape by the passages  $p$ . If the crude iron is run into the vessel at a low heat, or only a little above its fusing temperature, it will be found rapidly to increase in temperature and at the expiration of about fifteen minutes from the time of commencing the process large frothy slags will begin to be thrown violently out of the passages  $p$ , accompanied by a rush of bright flame. After a few minutes' duration this eruption of slags entirely ceases, but a copious flame still continues to escape by the passages  $p$ . The crude metal at this stage of the process has thrown off the bulk of its im-

purities and in a few minutes more is in the condition of cast-steel. The exact state of the metal may, however, be ascertained by turning the handle and shaft *f*, so as to bring the vessel on its axis into the position shown in Fig. 6; and thereby discharge a small quantity of metal into an ingot-mold, which should be quickly cooled and examined; and if found to be not sufficiently decarbonized, the handle should be reversed, the vessel lowered, and the process be continued until the metal is decarbonized and purified to the desired extent. From five to ten minutes' additional blowing is generally found sufficient to bring the metal from the condition of cast-steel to that of soft malleable iron. Whenever it is desired to suspend the operation of blowing for a short period, the vessel should be brought into the position shown in Fig. 5, where it will be seen that the upper surface of the metal is below the orifice of the tuyeres, so that the forcing in of the air may cease without the tuyeres becoming stopped up with fluid metal, which would be the case immediately the blast of air is stopped, provided the orifices of the tuyere-blocks were not raised above the surface of the metal in the manner described. In making malleable iron from crude pig-iron of No 1 or 2 quality, about thirty to thirty-five minutes is required for the whole process; but the exact point to stop the process so as to obtain metal of any degree of hardness between hard steel and soft malleable iron will soon be acquired in practice by the workmen, since the color and volume of the flame issuing from the passages *p* varies with the condition of the metal, and forms a good guide for the workman to judge by. He can also take a trial-ingot in the manner described at any stage of the process, if necessary. I have found that such an excess of heat is produced in the process that the metal continues to boil even after the blast of air has ceased, and although reduced to the condition of malleable iron is still so far above the melting-point of that metal that it is desirable to lower its temperature before casting or pouring it into molds. For this purpose I bring the vessel into the position shown in Fig. 5. I then stop off the supply of air and place a fire-tile over the orifice of the passages *p*, so as to prevent the heat from escaping too rapidly, and thus cooling and solidifying the surface of the metal. In this way the metal may subside and be gradually lowered in temperature and be brought into a proper condition for pouring or casting; or, in place thereof, it may be allowed to cool down and be stirred or worked and taken out of the vessel in masses.

I would here state that I am aware that it has before been proposed to subject crude melted iron to the action of streams of air or steam when flowing in a trough from a blast-furnace or from a refinery-furnace, also when in pig-beds; and it has been further proposed to apply streams of air and steam when puddling iron, heated and kept heated in a pud-

dling-furnace; but in all cases heretofore the rendering of crude melted iron into malleable iron or steel the iron has required to be heated in a suitable furnace by the continued combustion of fuel, whereas in the process above described the heat contained in the crude melted iron is increased and rendered sufficient for obtaining or producing the conversion of the iron into steel or malleable iron by the simple application of streams of oxygen applied to such a mass of melted iron; and I mention these facts in order the more fully to ascertain and define the peculiarity of this my invention, which I declare to consist in acting on a mass of melted, crude, or cast iron, (when in a suitable vessel,) by streams of oxygen, (contained in atmospheric air or otherwise,) and without the further consumption of fuel for heating the vessel or the iron, to convert such fluid crude or cast iron into steel or malleable iron. During the interval occupied in cooling down the boiling metal the workman should get his ingot-molds, when they are to be used, in a position to receive the still fluid metal. A convenient way of doing this is to place them in an iron truck mounted on wheels, which may be moved under the spout of the vessel, and pass out under the arched openings left in the frames *c c* for that purpose. I have not shown a truck with molds in the drawings hereunto annexed, because the mode of constructing it and its size and form may be varied to suit any particular form of ingot or mold that may be used; and which may be easily arranged by any intelligent workman. As soon as the casting of the ingots is completed, the mold should be removed and the vessel again lowered down into the position shown in Fig. 4, when the blast of air may be again turned onto the pipes *u* and *s*, and another charge of crude iron be run into the vessel to be treated in like manner. The process of decarbonization and refinement of the metal may thus be carried on until the metal is reduced to the condition of hard or soft steel, or to the condition of steely or soft malleable iron. In either state, the metal so refined may be poured from the vessel or chamber into suitable ingot-molds, for the purpose of being afterward hammered, tilted, or rolled into bars, rods, or plates by the processes already known and practiced in the manufacture of iron and steel. I would, however, remark that I have found in some cases that the ingots of metal contain cells or cavities. In such cases I subject the ingot at a welding heat to the action of a "squeezer," such as is used in the shaping of puddle-balls; or I subject the ingot to repeated blows in a swage or die under a powerful hammer, so that the parts are forcibly squeezed, pressed, or driven together, and the pores closed and the surfaces united or welded together prior to subjecting such ingots to the rolling-mill or tilt-hammer. In carrying into practical operation this part of my said invention, it will be necessary for the workman to bring up the in-



got or mass of metal to such a temperature as will soften it sufficiently to allow the cavities in its interior to close up and unite, so as to form it into a compact solid body. When using a machine of the kind used for squeezing puddle-balls, I prefer to form transverse grooves both on the lower and upper jaws of the squeezer, as represented at Fig. 1, Sheet B, of drawings hereunto annexed, which represent so much of a squeezer as is necessary to show the peculiarity described, A A being the grooves or hollows, and B an ingot placed between the jaws. A similar effect on the ingot is produced by first hammering it in a "swage," as shown at Figs. 2 and 3, Sheet B, of the annexed drawings, where C represents the lower portion of a steam-hammer having a grooved block or swage, D, fitted to it. A similar block, E, is secured to a heavy mass of metal, F, which forms the bed of the hammer. The workman, after having heated the ingot G, will hold it with a pair of tongs in the groove of the lower block, while the upper one falls upon it with such force as the man who works the hammer may consider necessary. By the use of these grooved surfaces or swages the cast ingot of metal is less liable to be broken than when hammered between two parallel flat surfaces, which do not afford any support to the sides of the ingot. The workman will move the ingot backward and forward, and turn it over on its other side, and thus work and compress the metal until he judges that it is sufficiently solidified to be suitable for the tilting or rolling mill.

Figs. 4 and 5 represent a similar arrangement to the foregoing, the shape of the ingot being hexagonal in cross-section, instead of square, as in the former case. A more perfect support to the sides of a square bar is, however, obtained by using a swage of the form shown at Figs. 6 and 7, in which a square or nearly square notch or groove is formed at H, Fig. 6. In the lower block a corresponding raised projection, J, is formed on the upper or hammer block, by means of which the tendency of the sides of the ingot to crush out is to a great extent prevented. However, it will be found that in all these shapes or modifications of the swage or forging surface, the metal, although considerably protected from spreading and giving way laterally, is at liberty to extend itself in the direction of its length, and is, therefore, liable to be driven out in that direction, and thus escape from much of the force of the blow and also to become broken. To obviate these disadvantages, I use a die or cavity in which the metal is placed, so that when an ingot or other mass of metal refined, as hereinbefore described in a soft or welding state, is put into the die, it may receive the most powerful blows or pressure without its parts being broken or scattered about; but it will, on the contrary, be retained within the said die cell or cavity and become there consolidated and have its pores so closed and united, so as to be in a condition suitable for the ordinary

forging or rolling process. This effect may be produced by several different modifications of apparatus, the details of which are not of much importance, provided that the dies are so constructed that the ingot or mass of cellular or spongy malleable metal, whether iron or steel, be so confined within the said die, cell, or cavity that when a plunger or hammer is forcibly brought in contact with it, it may thereby be prevented from being dispersed or spread out, but will, on the contrary, be so retained in the said die, cell, or cavity that it will, by the force thus brought to act upon it, have its various parts forcibly squeezed, pressed, or driven together, and the pores closed and the surfaces united or welded together. In order that the means by which this part of my said invention may be carried into practical operation may be understood, I have shown on Sheet B of the drawings hereunto annexed so much of the apparatus as is required to render the following description thereof intelligible.

Fig. 8 represents an elevation of the die or cavity, in which the metal is pressed. It consists of a massive ring or hoop, M, made of wrought-iron, with a lining of steel; or it may be made of chilled cast-iron hooped with wrought-iron. It has a square hole passing through it which is parallel, or nearly so. Into this hole the anvil-block N is fitted in such a way that the hoop M may slide freely up or down. O represents a portion of the bed or foundation plate of a steam-hammer, to which the anvil-block N is secured. The hammer-block P has attached to it a hammer or plunger, Q, fitted also to the hoop M.

At Fig. 10, a section of the die is shown having a block of metal, R, placed within it, ready to receive a blow from the hammer. By reference to the drawings it will be seen that the hoop M is supported by two guide-rods, S, which are bolted to it, and which pass down freely through holes formed in the bed O, and by means of which the hoop may be raised or lowered, as required. In using the die under a steam or other suitably worked hammer, the hoop is raised by a lever attached to the rods S, so as to keep it in the position shown in Fig. 10. The heated ingot or mass of metal E is then placed on the die, and the plunger or block Q is brought down with great force. Several powerful blows having been given to the metal in rapid succession, the hoop M is to be lowered down by means of the lever before named until it reaches the position shown in Fig. 11, when the ingot may be turned over by the workman and the hoop M again raised and the hammering of the ingot be repeated, after which the hoop may be again lowered and the highly-compressed ingot removed, in order that the apparatus may be made to operate in like manner upon other ingots. The upper ends of the ingots are sometimes too unsound to form a perfect bar, in which case I cut or break them off and return such scrap or waste pieces to the decarbonizing-chamber at the time of refilling it

for another operation; and so, in like manner, other scrap metal resulting from the spilling or splashing of the fluid metal, and also the bar or crop ends and shearings from the plates or bars of rolled metal may thus be brought into use by remelting them in the fluid metal contained in the converting-vessel without the use of any fuel for that purpose. I have herein described how malleable ingots of iron or steel are to be made by a direct process of refinement from crude iron without the application of heat or fuel to the iron during the process, except such heat as is generated by the introduction of oxygen into the metal; and I will now describe a modification of the process by which I prepare the iron for conversion into steel of a superior quality. For this purpose I proceed in the first place to refine the crude iron in the manner hereinbefore described, carrying on the process until the most complete refinement is effected and the iron is as nearly pure as may be. I then pour the fluid iron into water, by which it becomes granulated, and the grains or shots so produced are afterward to be converted into steel by the process of cementation with charcoal in upright retorts, in the manner described in a patent granted to me in Great Britain for improvements in the manufacture of cast-steel, and mixtures of steel and cast-iron, and bearing date the 18th day of June, 1855. The blister-steel so produced may be melted in

crucibles, as at present generally practised in the manufacture of cast-steel, or by any other suitable means.

Having thus described my 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 specified, provided that the peculiar character of my said invention be retained. I do not claim injecting streams of air or steam into molten iron for the purpose of refining iron, that being a process known and used before; but

What I do claim is—

The conversion of molten crude iron or of remelted pig or finery iron into steel or into malleable iron, without the use of fuel for reheating or continuing to heat the crude molten metal, such conversion being effected by forcing into and among the particles of a mass of molten iron currents of air or gaseous matter containing or capable of evolving sufficient oxygen to keep up the combustion of the carbon contained in the iron till the conversion is accomplished.

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