Sheet 1 - 2 Sheets

C. W. Siemens,
Making Cast Steel,

No. 93,758, Patented Aug. 17, 1864.

Fig. 1.

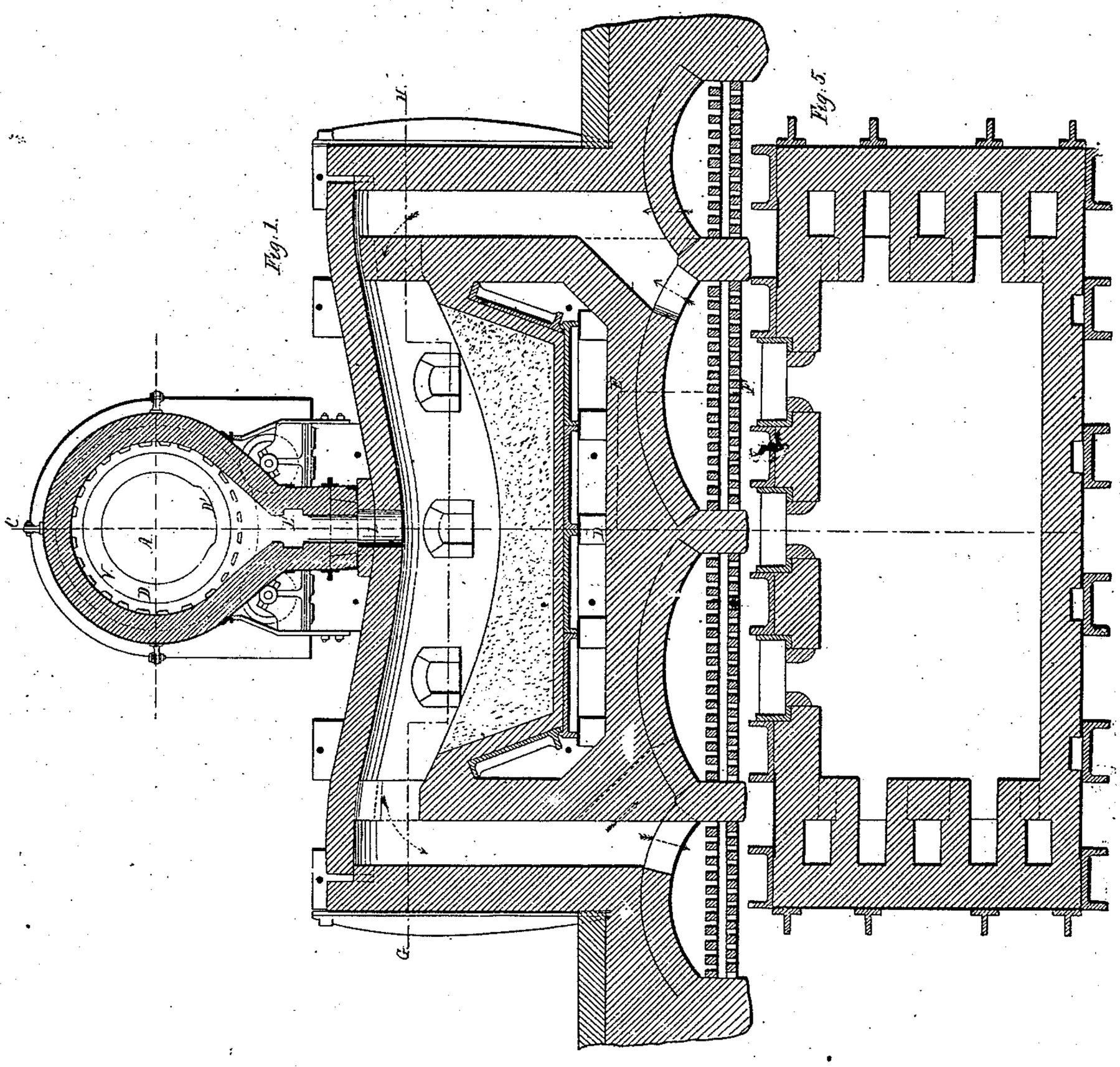

Fig. 5.

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J. R. Snow

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by his attorney.
R. H. Eddy

Sheet 2 - 2 Sheets

C. W. Siemens,
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No. 93,758 Patented Aug. 17, 1869.

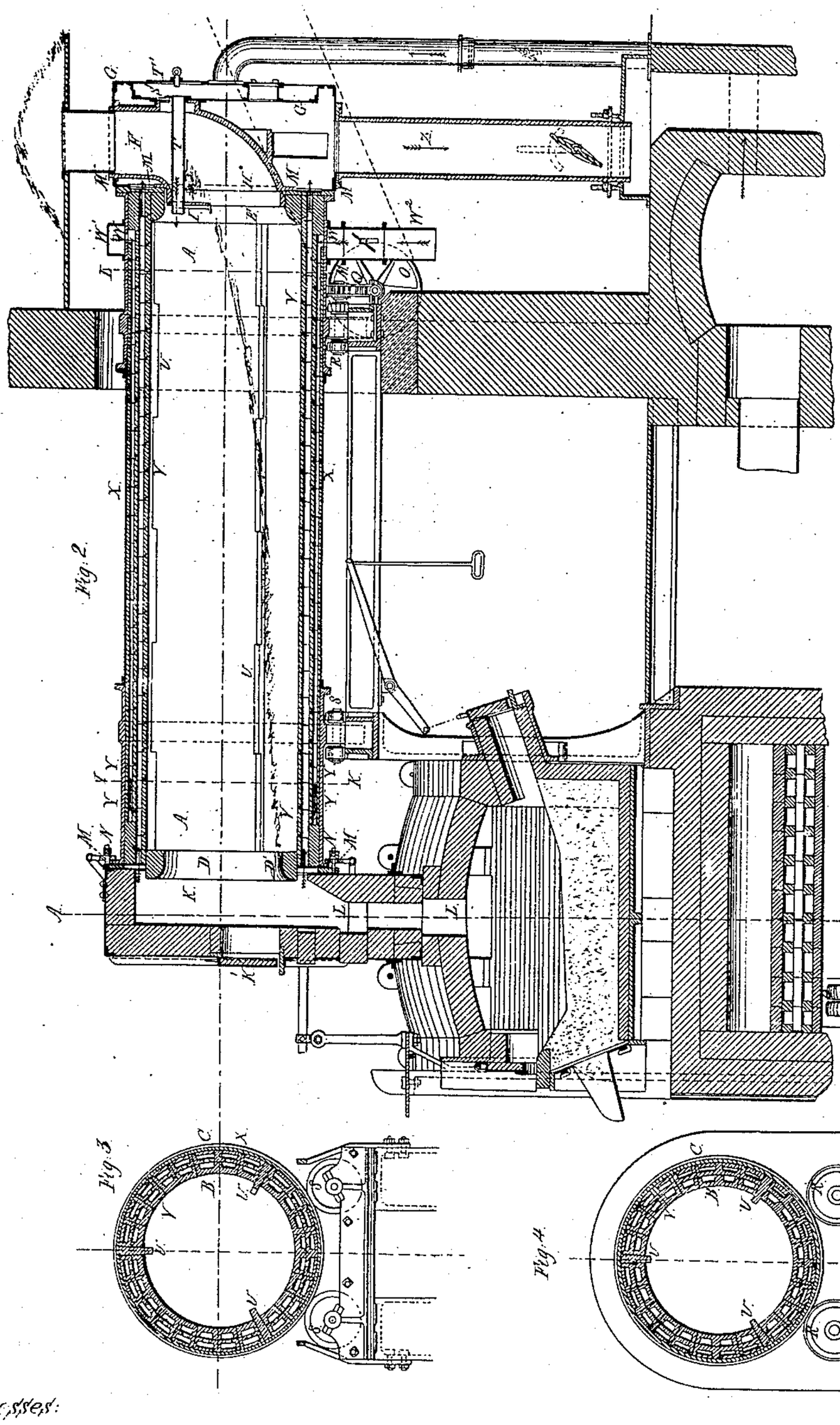

Fig. 2.

Fig. 3.

Fig. 4.

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United States Patent Office.

CHARLES WILLIAM SIEMENS, OF WESTMINSTER, ENGLAND.

Letters Patent No. 93,758, *dated August* 17, 1869.

IMPROVEMENT IN MAKING CAST-STEEL.

The Schedule referred to in these Letters Patent and making part of the same.

To all persons to whom these presents may come:

Be it known that I, CHARLES WILLIAM SIEMENS, of Westminster, in the county of Middlesex, England, have made a new and useful invention, having reference to Furnaces, Apparatus, and Processes for the Production of Steel direct from iron-ore; and do hereby declare the same to be fully described in the following specification, reference being had to the accompanying drawings, and to the figures and letters marked thereon; that is to say—

My improvements have reference principally to the process of, and apparatus for making steel, described in the specification to certain Letters Patent granted to me, and bearing date April 27, 1869.

Instead of reducing the iron-ore in vertical hoppers descending into the metallic bath, as described in the specification to the said patent, I effect its reduction in one or more revolving cylinders, drums, or muffles, which are placed horizontally, or nearly so, above the melting-furnace.

The revolving cylinder, or muffle, is lined with fire-brick, or other refractory material, and is heated by means of flues or passages in the substance of its lining, through which flame is made to circulate.

The ore to be reduced, which is mixed, by preference, with a certain proportion of solid reducing-agents, and with suitable fluxes, is fed in at the one extremity of the rotating cylinder, and is worked gradually forward by its rotation, while the ore at the same time is heated to redness by the heated lining of the cylinder.

Reducing-gas is made to enter the cylinder at the charging, or both ends, through an opening in or near its axes, and, being brought extensively into contact with the heated and moving ore, effects its entire and uniform reduction into spongy or pulverulent metallic iron, which latter falls, in due course, through a vertical hopper or channel into the melting-furnace, where it is readily dissolved and incorporated with the bath of fluid cast-iron previously prepared on the bed of the furnace, or is brought into contact with an excess of solid carbon, charged upon the hearth of the furnace, to form, with the spongy reduced metal, the commencement of a liquid bath of steel or cast-iron.

The reducing-gases employed also escape from the further end of the rotating cylinder into the heating-flues or passages, arranged, as already mentioned, in the substance of the lining where atmospheric air is admitted to burn them, the products of combustion escaping from the said flues near the charging-end toward a chimney, and the draught being regulated by dampers.

Instead of effecting the reduction of the ore within the rotating cylinder entirely, or even partially, by means of reducing-gases, solid reducing-agents, such as anthracite, coke, charcoal, sawdust, or peat, may be employed with or without the addition of pitch, tar, oil, or resinous substances.

The same reducing-apparatus may also be employed for the production simply of spongy or pulverulent metallic iron. In this case the place of the melting-furnace is taken by a sheet-iron casing, in which the reduced iron is cooled down without access of air.

In the manufacture of cast-steel, or of spongy reduced iron directly from the ore by the above process, pure oxides of iron, such as many hæmatites and magnetic ores, may be charged into the reducing-muffle, without any preparatory treatment, but ores containing any volatile constituents, such as carbonic acid or water of hydration, should be calcined before they are charged into the muffle.

Ores contaminated with sulphur, phosphorus, or arsenic, should be calcined, and washed after calcination, to remove from them these impurities as much as possible.

Another part of my invention has reference to certain modifications in the method of purifying or improving the quality of the bath of liquid steel in the furnace, by the introduction into it of certain chemical reagents, before it is lapped out and cast into ingots, as has been already described in the specification of my before-named patent, bearing date April 27, 1869.

Having thus premised, I will now proceed more particularly to describe my invention.

Figures marked 1 to 5 of the accompanying drawings show the arrangement of reducing-muffle and steel-melting furnace, for the production of cast-steel directly from the ore.

Figure 1 shows a longitudinal section of the melting-furnace and regenerators, and a transverse section, through the discharging-end of the revolving muffle or drum, on line A B, fig. 2.

Figure 2 shows a transverse section through the melting-furnace, and a longitudinal section through the reducing-muffle, on line C D E F, fig. 1.

Figures 3 and 4 show transverse sections through the reducing-drum, on lines I K and L M, fig. 2.

Figure 5 is a sectional plan through the melting-furnace, at G H, fig. 1.

Similar letters of reference indicate similar parts in each of the figures.

The melting-furnace itself is similar in construction to that described in the specification to my previous patent, to which I have before referred.

In the arrangement of furnace which is described in the specification just named, the reduction of the ore was effected in two vertical chutes or hoppers, placed above the bath of liquid metal in the melting-chamber, into which the ore gradually sank down by gravity as it was reduced.

According to my present arrangement, the ore is

reduced in a rotating cylinder or drum, A A, which rests (in a horizontal position, or about so, above the melting-furnace) on four rollers, as shown on figs. 1 to 4 of the accompanying drawings.

The outer casing of the drum A A is divided into three sections, the middle portion being made of strong wrought-iron plates, and the ends of cast-iron, as shown on fig. 2 of the drawing.

This outer shell of the reducing-cylinder A A is lined throughout its length with two courses of hollow fire-bricks B C, which are so arranged as to leave a double series of small flues or passages in the substance of the lining, extending from the one extremity of the cylinder to the other, as shown in figs. 2, 3, and 4.

The opening of the cylinder is diminished at each end by the addition of inner rings of lining-bricks D E.

The ore is introduced at the one extremity of the revolving drum, through a cast-iron chute, F, attached to the fixed sheet-iron casing G.

The chute F is kept always filled with ore, which is fed gradually forward into the reducing-muffle through the circular opening H, the thickness of the bed of ore in the muffle being regulated by the plate I, which closes more or less the upper part of the charging-opening H.

The other extremity of the reducing-cylinder opens into a second sheet-iron casing, K, which is lined with fire-brick, and communicates directly, by the small opening L, with the bath of the melting-furnace below.

The two casings G and K, at the ends of the revolving cylinder A A, bear closely against it, by means of accurately-turned faces at M M M, and are kept in contact with it by screw-clips N N, fig. 2, the casings G K being both so supported that they are free to adjust themselves closely to the ends of the revolving cylinder A A.

The cylinder is carried by two pairs of rollers, R R and S S, figs. 2, 3, and 4, and is put in motion by the driving-arrangement shown in figs. 2 and 4.

A pulley, O, driven by a band, or in any other convenient manner, communicates motion through two endless screws P P, and two worm-wheels Q Q, to the rollers R R, already mentioned, which support the greater part of the weight of the cylinder A A, when it is filled with ore, and which drive it by friction.

By the slow rotation of the reducing-cylinder or muffle, the ore introduced through the chute F, from the charging-floor above, is continually turned over, and each portion of it is exposed in succession to the action of the reducing-gas, which is introduced through the tube T, fig. 2.

To prevent the slipping round of the ore in the mass inside the muffle, in which case the surface only would be exposed to the action of the gas, rows of projecting bricks are built into the lining, at intervals, as shown at U U, figs. 2, 3, and 4, between the bricks B C.

These projecting bricks carry the mass of ore round with them, preventing any slipping, and forcing the ore to roll over and over, exposing every part equally to the reducing action of the gas.

The excess of reducing-gas is drawn away, at the end D of the muffle, into the series of small flues V V in the brick lining.

Air is drawn in at the same time through a series of openings, W W, fig. 2, provided with slides or regulators.

In traversing the whole length of the outer series of flues X X, the air drawn in at W W becomes more or less heated before it meets with the gas at the apertures Y Y, and burns with it along the inner flues V V, heating the muffle to bright redness, and escaping at length into the casing G, and thence through the tube Z, fig. 2, which is furnished with a valve for regulating the draught, into the main chimney-flue.

The mode of working this furnace is as follows:

The reducing-cylinder is, in the first instance, heated to redness, and the melting-furnace below is raised to a full steel-melting heat.

The cylinder is then put into slow rotation round its axis, and the ore, which I suppose to be hæmatite, mixed with from ten to fifteen per cent. of its weight of solid reducing-agents, such as anthracite, coke, charcoal, or with a somewhat larger proportion of sawdust or peat, and about three per cent. of lime, is filled in at the one extremity through the chute F, from the charging-floor above, a supply of reducing-gas being introduced, at the same time, through the tube T, fig. 2.

The reducing-gas, as it passes through the box T', and the ore descending in the curved chute F, are heated by the waste gases, on their passage toward the chimney-flue.

The reducing-gas employed is ordinary producer-gas, consisting principally of carbonic oxide and nitrogen. It should be washed thoroughly before it is introduced, through the box T', fig. 2, and the tube T, into the reducing-muffle, in order to condense and remove, as completely as possible, the water-vapor that it may contain, and to purify it from sulphurous acid and other injurious compounds.

Although I mix with the ore, as already mentioned, from ten to fifteen per cent. of solid carbon, in any form or combination which does not contain sulphur, phosphorus, or other deleterious substances, (among which forms wood and peat deserve special mention,) I depend, also, upon the carbonic oxide introduced into the muffle for effecting the reduction of the ore.

The gas entering at T is brought, by the rotation of the drum, into extensive contact with the heated ore, but inasmuch as its reducing-action would cease as soon as a considerable proportion of the carbonic oxide contained in it had been converted into carbonic acid, (as shown by Le Play and others,) the presence of solid and heated carbon is necessary, in order to bring the carbonic acid back again to the state of carbonic oxide, unless, indeed, a vastly excessive quantity of gas were passed through the reducing-drum, which would be attended by waste.

If such solid reducing-agents are employed as wood or peat, these should be dried completely before they are charged in with the ore; and inasmuch as reducing-gases will be evolved from them by heat, the admission of gas at T may be greatly diminished when they are employed instead of pure solid carbons; but, on the other hand, they must be added in an increased proportion, to bring up the solid carbon to from ten to fifteen per cent., according to the nature and richness of the ore. Nevertheless, the use of gases cannot be wholly dispensed with, except at a risk of irregular and imperfect reduction of the ore.

The temperature within the reducing-cylinder should be maintained during the process at a full red heat, or from 600° centigrade to 900° centigrade toward the end where the discharge takes place, but diminishing toward the charging-end.

By the slow rotation of the cylinder, a portion of the reduced pulverulent metal is discharged through the opening L into the bath of liquid cast-iron, (which is maintained in the melting-furnace below,) at each revolution of the drum, when the notch D', figs. 1 and 2, in the brick ring D, at the end of the muffle, comes into the lowest position, as shown in the drawings.

The rate at which the reduced metal is fed into the furnace depends, on the one hand, upon the velocity of rotation of the muffle, (which should be under perfect control,) and on the other, upon the inclination of the upper surface of the bed of ore. This last is

regulated by closing, to a greater or less extent, the upper part of the charging-opening H, fig. 2, by means of the plate I, which can be readily changed either for a deeper or a shallower plate.

By suitably regulating the speed of rotation of the muffle, the successive charges of reduced spongy iron are dropped into the bath of liquid metal in the melting-furnace, in proportion as each previous charge is dissolved.

The metal in the bath is stirred occasionally, and small samples are taken out at intervals, in the manner described in the specification to my previous patent, bearing date April 27, 1869. Additional charges of pig-iron are introduced if the metal is found to become decarburetted too rapidly; and when a sufficient amount of liquid metal has accumulated in the bath, and so much reduced spongy iron has been added as to bring the metal into the condition of liquid soft iron, containing not more than one to two per cent. of carbon, the rotation of the drum is stopped, and from five to eight per cent. of ferro-manganese or *spiegel eisen* is charged in, as described in my previous specification, above referred to; or the metal is treated in any other known manner, and is tapped out and cast into ingots or other forms.

The addition of *spiegel eisen* at the end of the process may be dispensed with if the ore is rich in manganese, or a second reducing-muffle may be added, charged with ore rich in manganese, and worked at such an increased temperature as may be necessary for the reduction of that metal to be used last in that operation.

The addition of *spiegel eisen*, or manganese in other forms, may also be dispensed with in the production of steel for castings which are not to be hammered, and need not, therefore, be so thoroughly purified as forge-ingots.

If hardness and tensile strength is the principal object, rather than ductility and elasticity, the carbon may be maintained with advantage, in such casting, at from one to two per cent., by an abundant use of the reducing-agents. A comparatively low furnace-temperature will suffice for such metal.

The reducing muffle remains stationary until the charge of steel has been tapped out of the melting-furnace and a fresh bath of liquid pig-iron has been formed; but the reduction of the ore is still continuously carried on in it, by maintaining the supply of reducing and heating-gas. If the ore employed is in the state of fine powder, it may be desirable to turn it over occasionally during this period, in order to expose it more thoroughly to the action of the gas.

In this case, the muffle may still be rotated a little at intervals, the reduced metal being kept from falling into the melting-furnace below, by pushing it back from the end of the muffle, by a rake, put in through the door K'.

The muffle may be entirely shut off, if required, from the melting-furnace, by inserting a slab of fire-clay into the connecting-channel L, at L'.

A furnace, as represented in the drawings, when properly constructed, is capable of producing three charges of cast-steel per twenty-four hours, of from three to four tons each charge, but the dimensions of these furnaces may be varied considerably. Thus, in producing steel of high quality and rich in carbon, such as tool-steel, it will be found convenient to employ furnaces of less capacity, whereas, in making large castings of steel, such as guns, bells, and armor-plates, or ingots for engine-shafts, furnaces of a capacity exceeding five, six, or even ten tons, may be employed.

The contents of several furnaces may be poured into the same mould, either by running them in directly from the tapping-holes, or by running the metal first into ladles, and then into the mould or moulds. I heat these moulds or ladles beforehand, by any suitable means.

The materials to be employed in the process above described, should be as pure as possible. The pig-iron should be, by preference, charcoal pig-iron, containing manganese, or the purest qualities of coke, made from hæmatite, magnetic, or spathic ores; though inferior pig-irons may also be employed, to a greater or less extent, in making the lower qualities of steel, the metal being purified, before tapping it out of the melting-furnace, by the introduction of chemical reagents, in the manner described hereafter. The ore should be a pure oxide of iron, containing but little gangue or earthy matter, and as free as may be from compounds of sulphur, phosphorous, and arsenic. Magnetic ores, hæmatite ores, or rich calcined spathic ores are particularly suitable. The ore may be in the form of powder, sand, or dust, and on this account many ores are suitable for this process, which, notwithstanding their purity, cannot be employed in blast-furnaces, amongst which the magnetic sands of Canada, Spain, and New Zealand, the micaceous ores, and the refuse ore produced in treating pyrites for copper and sulphur, may be especially mentioned. If the ore employed is in the state of powder, and therefore not pervious to the reducing-gas, I prefer to mix it with loose and pervious reducing-agents, such as wood in small pieces, sawdust, dried peat, or charcoal, or with pitch, asphalt, or oils, as already described by me in former specifications.

The nature and amount of the fluxing-material to be added depend on the foreign substances contained in the ore. In some cases, such a mixture of ores may be adopted as contains both silica and fluxing-material, such as lime, magnesia, or manganese, in suitable proportions, thus avoiding the necessity of any separate flux. Hæmatite or magnetic ores, containing silica, may, for example, be mixed, with advantage, with spathic ores, containing lime, magnesia, or manganese, or with clay ironstones. If nearly pure oxides of iron, such as some hæmatites or magnetic ores, or calcined spathic ores, are treated, I sometimes employ no fluxing-material, except a small percentage of oxide or carbonate of manganese, which forms, with the small proportion of earthy matter invariably associated with the ore, sufficient slag for the protection of the molten metal.

The ores, before use, should always be crushed into powder, or into pieces not exceeding the size of peas or beans, in order to facilitate their reduction into pulverulent or spongy iron. They should be mixed intimately with the fluxing-material that is added. If they contain volatile constituents, such as carbonic acid, water of hydration, arsenic, or sulphur, they should also be calcined.

Ores containing sulphur in the form of sulphide of iron, should be calcined carefully, at a very low heat, and subsequently washed, in order to remove as large a proportion as possible of the sulphur as soluble sulphate of iron.

The proportion between the cast-iron and the ore employed in the production of cast-steel, by the above process, may be varied between very wide limits.

In case rich ores, not containing sulphur or phosphorus in any notable quantity, can be obtained at a moderate price, it is advantageous to reduce the ore to metallic iron as completely as possible, by employing a large reducing-muffle, heated in the interior nearly to whiteness, and by mixing the ore with an abundant proportion of reducing-agents. It is sufficient, then, to commence the operation with no more than from ten to fifteen per cent. of cast-iron in the bath of the melting-furnace.

The use of pig-iron for the purpose of dissolving the reduced spongy metal, may even be dispensed with altogether by throwing on the bed of the melting-fur-

nace a considerable quantity of charcoal or of pure coke, or of anthracite, before commencing the introduction of the reduced ore from the muffle; or the extra proportion of solid carbon may be advantageously charged either wholly or partly into the reducing-muffle itself, through the door K', before the commencement of each operation, in order that it may be mixed intimately with the reduced metal before this reaches the melting-heat of the furnace. The effect of this excess of carbon is to carburet very highly the spongy iron first charged in from the muffle, thus forming a bath of liquid pig-iron on the bed of the furnace in which the remainder of the reduced metal is subsequently dissolved in the usual manner.

Charcoal, coke, or anthracite may be thrown upon the surface of the bath from time to time during the process, if the liquid metal is found to become decarburetted too rapidly.

On the other hand, in those localities in which the price of rich and pure ores is high, and in which a sufficiently-pure quality of pig-iron may be obtained at a price comparatively moderate, it is preferable to employ a smaller reducing-muffle, (through which the ore will pass more rapidly,) and to maintain it at a lower working-heat, in order that the reduction of the ore may be effected in part only. A much larger proportion of cast-iron may, in this case, be charged into the bath, even up to eighty or ninety per cent. of the steel produced.

The same reducing-apparatus may also be employed for the production simply of spongy or pulverulent metallic iron. In this case the place of the melting-furnace is taken by a closed sheet-iron casing, into which the reduced spongy metal falls from the end of the reducing-cylinder, and in which it is cooled down without access of air.

Instead of producing cast-steel, by the use of ores and pig-metal only, as hereinbefore described, the bath may be increased by charging into the same furnace waste ingots from previous operations, scrap-iron, or steel, or balls or blooms of puddled or otherwise refined iron or steel, by whatever process it may have been produced, or the spongy or pulverulent iron produced in an independent reducing-muffle may be charged into the melting-furnace, if the muffle or muffles attached to the furnaces are not in order, or do not, by themselves, furnish to it a sufficient supply of reduced metal.

In working up, in the melting-furnace, such spongy iron, reduced in an independent reducing-muffle, or light scrap, as, for instance, steel or iron-turnings, or punchings or clippings of sheet-iron or steel, it is advantageous to heat the metal before introducing it into the bath, by charging it through the heated reducing-muffle, which, in the above-described process, is employed for effecting the reduction of the ore.

I am aware that Thomas J. Chubb, of Brooklyn, New York, obtained a patent in the United States of America, No. 65,473, dated June 4, 1867, for the manufacture of steel direct from iron-ore, by forming certain pure or purified iron-ores into cakes, balls, or cylinders, by the addition of glutinous matter, and also by covering such cakes or lumps with clay or boxes of iron, and subjecting the same to heat in an inclined and fixed tunnel or muffle, provided with openings and covers on the top, through which the said cakes may be pushed forward toward the hotter end of the said tunnel, thence passed through a partition or partitions into another muffle or pot, where the reduced metal is to be melted in a bath of steel, the partition between the melting-furnace and the reducing-tunnel being kept closed, except when the reduced ore is to be introduced into the melting-muffle or pot.

My invention differs essentially from such plan, inasmuch as it is entirely self-acting, and the iron-ore is used as coming from the mine, or calcined, and merely broken into pieces, and is fed loose, together with the reducing-agents, into a horizontal revolving cylinder, in which it is reduced in the presence of a gaseous atmosphere, by means of heat produced by the combustion, within the lining of the revolving cylinder itself, of the surplus gases which have served for the reduction of the ore; and also in that my revolving and reducing-cylinder is constantly in communication with the melting-furnace.

Further, in my invention, instead of using muffles or pots, which are expensive, and liable to crack and break, and wear out quickly, in which the reduced ore is melted, my furnace is made with a sand bottom, which may be repaired at the end of every charge, and, instead of using a bath of melted steel for the melting of the reduced ore, I use a bath of cast-iron, or simply carbon, which is cheap and advantageous, as the metal is thereby kept melted at a lower temperature, thus causing less wear and tear of the furnace, and less expense for fuel.

Moreover, in my invention another distinctive feature is, that when sufficient metal has accumulated on the furnace-hearth, I then treat it with manganese, titanic or other ores or metals, *spiegel eisen*, and other refining-agents, before tapping it out into the ladles for running into ingots, by which means great regularity and certainty as to the quality and temper of steel are insured, samples being taken out at intervals, which may be tested for this purpose.

I am also aware that Thomas J. Chubb, of Williamsburg, New York, obtained a patent in the United States of America, No. 79,314, dated 30th June, 1868, antedated 15th January, 1868, in which he proposes to reduce ores in contact with carbon, and in vertical chutes, provided, or not, with inclines, on which the materials, in their descent, are supported, and for the use of stirrers and bars in the said chutes to assist the descent, and for the use of clay crucibles and muffles in a regenerative gas-furnace, for melting such steel.

My present invention is quite distinct from such arrangement, inasmuch as I do not make use of any such vertical chutes, or inclines, or crucibles, or semi-circular muffles, having, in 1866, obtained a patent in England for use of my regenerative gas-furnaces, as applied to the fusion of steel in pots, such patent being numbered 671; and having obtained a patent in England for the use of my regenerative gas-furnaces, in conjunction with inclined surfaces and oils, for the production of steel direct from the ore, this latter patent being taken in 1866, No. 2,413.

Having thus described the nature of my invention and the best means I am acquainted with of performing the same, I wish it to be distinctly understood that I do not confine myself to the details of apparatus hereinbefore described, as these may be variously modified without departing from the nature of my invention. Nor do I claim the regenerative gas-furnace hereinbefore mentioned, apart from its combination with the reducing-apparatus or rotative cylinder, as explained. Nor do I herein claim the manufacture of cast-steel in large masses directly from the ore.

What I claim as of my present invention is as follows:

I claim the method, substantially as hereinbefore described, of producing cast-steel from the ore, such consisting in causing iron-ore, in small pieces or in powder, to pass through and be treated by one or more horizontal or slightly inclined revolving cylinders, (acting as hereinbefore explained,) and next causing such ore to fall or pass into a bath of pig-metal or carbon (previously prepared) on the open hearth of a furnace, and thereby be melted or otherwise treated, and changed more or less into malleable cast-steel by the addition of one or more refining-agents, substantially as hereinbefore described.

I also claim, for the reduction of iron-ore in manner

as set forth, an apparatus consisting of a revolving cylinder or drum, as described, provided with outer channels, arranged substantially as specified, through which, when in use, the gases resulting from the reduction of the ore within the drum may be caused to pass, and be consumed in connection with air introduced into and heated within certain of such channels, as described.

I also claim the combination and arrangement, as set forth, of one or more rotative cylinders or drums, as explained, with a furnace, as described, (or its equivalent,) for the production of cast-steel direct from the ore, as set forth; the whole being substantially as described.

C. W. SIEMENS.

Witnesses:

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