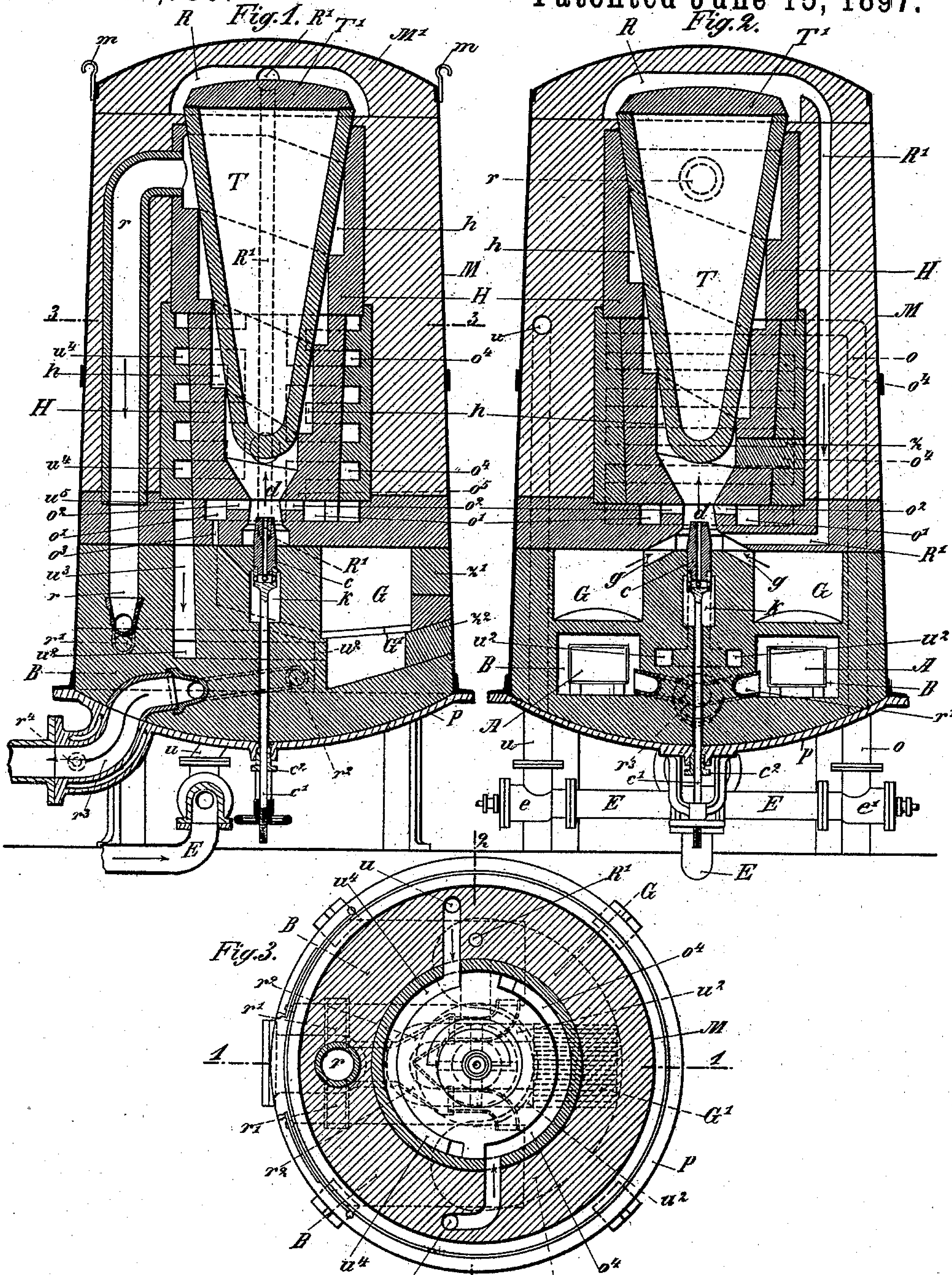
(No Model.) 2 Sheets—Sheet 1.

C. J. L. OTTO.

METHOD OF AND FURNACE FOR MAKING IRON AND STEEL DIRECTLY FROM ORE.

No. 584,730. Patented June 15, 1897.



Witnesses:
Thomas Durant
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Inventor:
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his Attys

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2 Sheets—Sheet 2.

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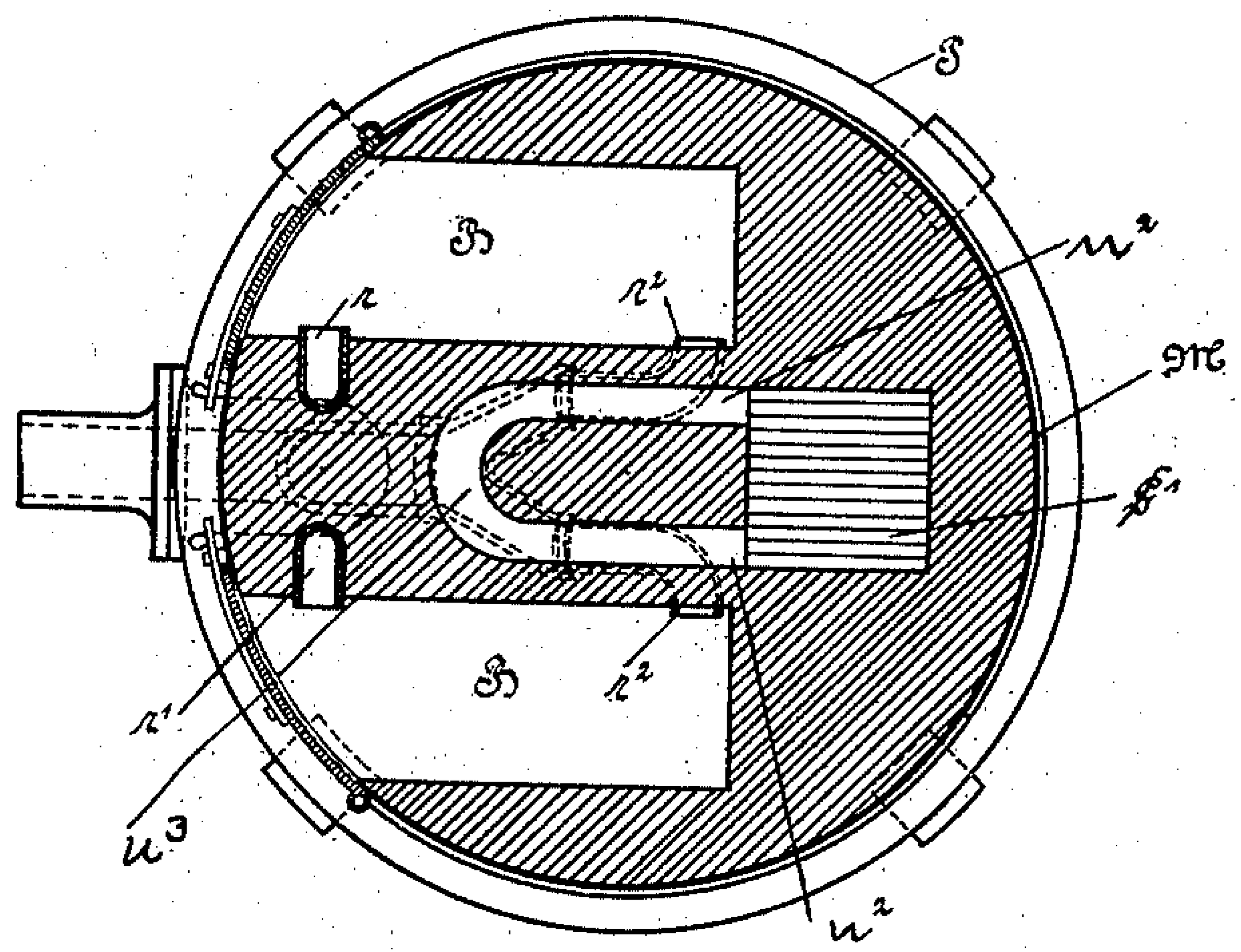
Fig. 4.



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UNITED STATES PATENT OFFICE.

CARL JOHANN LUDWIG OTTO, OF DRESDEN, GERMANY.

METHOD OF AND FURNACE FOR MAKING IRON AND STEEL DIRECTLY FROM ORE.

SPECIFICATION forming part of Letters Patent No. 584,730, dated June 15, 1897.

Application filed February 8, 1896. Serial No. 578,589. (No model.)

To all whom it may concern:

Be it known that I, CARL JOHANN LUDWIG OTTO, a subject of the King of Prussia, German Emperor, residing at Dresden, Kingdom of Saxony, German Empire, have invented a certain new and useful Method of and Furnace for Making Iron and Steel Directly from the Ore, of which the following is a specification.

The direct production of wrought-iron from the ores has not been hitherto a scientific success, as after a long process and considerable consumption of fuel the result has been spongy iron saturated with slag, the further treatment of which is not only complicated and expensive, but also considerably diminishes the quality of the product on account of oxidizing influences which it is impossible to avoid. To obviate these drawbacks, I propose to melt the iron in a reduction-chamber in a neutral atmosphere under high pressure, but to let the reduction proper take place quickly at such a low temperature that iron of great purity remains and at the same time the formation of slags is prevented. I must completely reject the possible view that in the present apparatus a direct reduction takes place at a moderate temperature from a mixture of iron ore and coal—that is to say, the view that the carbon combines directly with the oxygen of the ore. As accepted already in similar processes, the process in this apparatus is reduction by previously-formed carbonic oxid. This shows that in the old process it was a mistake to let the carbonic oxid, which was strongly heated in open furnaces, expand freely and so act on the ore in an insufficiently dense state. With regard to this I use in my process a furnace in which the consumption of the fuel and the reduction of the ore take place under pressure. Such a furnace with compressed air fulfils at the same time the conditions of melting the spongy iron, for in such furnaces, as is known from Bessemer's experiments, the highest melting temperature can be reached in a quick and secure manner, even with a pressure of one atmosphere. Decomposition of the iron oxid by the same quantity of heat as became free at the formation of the oxid from metallic iron and the oxygen of the atmosphere could not be accomplished without expenditure of work, as the oxygen returning into its gaseous state has to overcome the atmospheric pressure. In limiting by using high pressure this work, which necessitates an extra expenditure of heat, the heat, equivalent to the work saved, is itself saved and used to furnish some of the heat which must be absorbed in the decomposition of the remaining portion of the ore, which has not been yet decomposed. The loss of heat which arises in course of the process in producing the pressure is easily recovered afterward from the outgoing gases during the quick decrease of temperature in these gases as they subsequently expand. Under pressure a part of that waste heat can therefore be used for the reduction, which is of great economical importance. The heat expenditure for the reduction, which latter is helped and made more rapid by the pressure, increases at the same rate at which the heat production for accelerating the process is increased in the high-pressure furnace. Therefore there is no necessity to overstep the moderate temperature, which is a necessary condition for the direct production of iron and for insuring the retention of the silicon, sulfur, and phosphorus in the slag. The dissociation of the carbonic oxid formed is prevented by the pressure thereon. The reducing action of the gas is still more increased by the elimination of the nitrogen, which gradually disappears from the reduction-space through diffusion. The furnace fulfils the condition of higher heat-supply, not by raising the pyrometrical, but by increasing the absolute calorimetric effect of the consumption-gases, which in relation to the space they occupy, being condensed, take up a greater quantity of heat than they would when expanded.

For the process the reduction vessel ought to be so shaped that the place where the iron to be produced collects is in that region of the furnace in which the temperature is the highest and sufficient for melting the spongy iron. As a rule this temperature will be reached only when the expenditure of heat for the reduction becomes smaller—*i. e.*, at the end of the process. A bath of molten metal in the mentioned place is advantageous. If it consists of highly-carbonized iron, then it gives steel production. The dissolution of the spongy iron formed in that molten bath can be facilitated by supporting the furnace so that it can move, in the style known in Bessemer converters, in order to bring more quickly the molten metal in contact with the spongy iron by swinging and inclining the furnace. Also iron ores containing gold and silver can be treated according to my process with simultaneous extraction of the precious metals. Some ore is, for instance, pyrites containing gold. In such case the highest temperature is to be kept up till the precious metal is deposited by liquation on the bottom of the reduction vessel.

Especially economical is my process when the escaping compressed gases are used according to Popp's method for compressed-fluid motors or when the energy of these gases is utilized in some other way which the release of gases during the reduction according to my description seems to invite. For this purpose the temperature of the gases is reduced by mixing them with cold air or by passing them through chambers in which heat-consuming processes are made to take place in order to distribute the heat on large masses. In such way the heat of the gases can be utilized, for instance, for preliminary heating and calcination of ores, for cementing the iron extracted, or for tempering of the cast-iron placed in the furnace.

Especially advantageous for the process appears to be a high-pressure furnace the gas-furnace of which can be easily regulated for producing any desired temperature and in which the highest temperatures can be produced with a small fuel consumption.

A similar furnace suitable for the process on a small scale is represented in the accompanying drawings.

Figure 1 is a longitudinal section of it along the line 1 1 of Fig. 3; Fig. 2, a longitudinal section along the line 2 2 of Fig. 3, and Fig. 3 a cross-section along line 3 3 of Fig. 1. Fig. 4 is a cross-section on line 4 4 of Fig. 1.

The furnace is connected by a pipe E with a pipe bringing compressed air and is surrounded by a jacket M, which is fixed by bolts to the foundation-plate P, which jacket can resist a pressure of several atmospheres.

From the generator G, which is fired through a grate G′, two canals *g g*, Fig. 2, lead to the hearth *d*, where also come at a little higher level the twyers for supplying the blast from the top. A conical piece *c*, with a hole in the middle, is in the opening made in the refractory brickwork leading from the air-chamber *k* to the hearth. By means of a spindle *c′* this cone *c* can be pushed from underneath into the conical neck of the hearth *d* when it is desired to decrease the draft c^2. The chamber *k* below the conical piece is connected with a circular canal *o′*, out of which come the twyers o^2, by means of a branch canal o^3, Fig. 1.

The blast-pipe E is divided into two upwardly-extended branches *u* and *o*, which can be shut off each separately by valves *e* and *e′*, Fig. 2. In Fig. 2 at the top on the right-hand side one of these branches *o* joins zigzag-shaped canals o^4, which lie around the shaft of the furnace in a half-circle and at the lower end o^5 join a canal *o′*, communicating with the hearth. Opposite this set of zigzag canals o^4 there are other similar canals u^4, which are joined at the top by the other blast branch *u*. These canals at their lower end u^5 merge into an upright canal u^3, which at the bottom is divided into two branches u^2, which enter passages *g*, debouching upon the conical piece aforesaid under the grate. The last-named blast branch *u*, with the other canals communicating with it, is the path for the blast coming from underneath. The other blast branch *o*, with its connections and twyers o^2, conducts the blast from the top to the flame. There is a great heating of the compressed air on its way through the zigzag channels.

The flame produced at the hearth develops in the furnace-shaft under the crucible T, which is surrounded by gaseous products of combustion in spiral flues *h*. These flues *h* are formed by the crucible resting close against the edges of stepped brickwork H, which edges have the shape of a spiral on a cone. Therefore the crucible-opening is closed to the fire-gases, which escape laterally through a suitable exit *r*. On the crucible there is placed a loose cover T′, which does not close hermetically and which allows the carbonic oxid developed in the crucible to escape. From the hollow space above the crucible-lid this oxid is led through a canal R′ to the hearth *d*. The canal *r*, leading from the spiral channels, is forked in the lower part of the furnace and two branches *r′* thereof lead to chambers B, which, according to my former explanations, are used for utilizing the heat of the outgoing gases and decreasing the loss of that heat. For this purpose in the chambers B, I can place cementing-boxes A. From the chambers B finally go canals r^2, which merge in a canal r^3, which leads to a reservoir or to a compressed-air motor. At r^4, Fig. 1, the compressed outgoing gases can be mixed, if desired, with cold compressed air.

To start the furnace, the outer jacket M thereof is lifted by means of hooks *m* by a crane and the inner furnace-structure made accessible by lifting the cover M′ thereof and the cover T′ of the crucible T and by taking out certain parts $z\ z'\ z^2$ of the structure, these parts consisting of blocks of refractory material which fit in corresponding openings and can be pulled out by means of iron hooks or the like. Then follows charging of the crucible and firing through the grate G′. The charge of the crucible ought to consist of a thorough mixture of ores and coal with the fluxes necessary for formation of fusible slag, or, if desired, should also comprise a bottom lining of iron or steel pieces for producing a molten bath. When all the apertures are closed, the jacket M is let down and screwed tightly in place. Valves e and e' are then opened in order to enable compressed air to be forced through the blast branches, the outlet-canal r^3 being temporarily closed. The blast from underneath enters through $u\ u^4\ u^5\ u^3\ u^2$ into the generator-chambers G below the hearth, while the top blast is supplied through its special canals $o\ o^4\ o^5\ o^2$ and twyers o' to the combustion-hearth d to be mixed with combustible gases escaping from the generator-chambers G G. For the combustion-hearth a peep-hole covered with mica is provided, through which the progress of the firing can be observed. According to that the conical piece e, aforesaid, can be adjusted when it is not possible to follow the changes of pressure. As the temperature at the beginning ought to be a moderate one and as the quantity of generator-gases is increased by addition of the carbonic oxid resulting from the process of reduction, the blast from the top has to be kept up strong in the beginning and then gradually to be decreased till finally an intense combustion takes place without superfluous air, which combustion secures melting of the extracted iron. When the process is finished, which is recognizable by the fact of the waste heat increasing in temperature, the furnace is opened, after the wind-supply has been closed and the still remaining pressure relieved, in order to lift out the crucible for producing the intended castings after the slag has been taken off.

The size and dimensions of the furnace and the manner of supporting the same form no part of the invention and are susceptible of modification, as will be apparent.

I claim—

1. The process of producing iron and steel direct from the ore, consisting in heating a mixture of the ore and coke in a closed vessel under high pressure and constant volume, carrying the carbon oxid produced in the reduction-chambers into the hearth and subsequently melting the spongy iron produced, in a neutral atmosphere without removal from the furnace, substantially as described.

2. The process of extracting precious metals from ore, consisting in heating the ore in a reduction vessel closed to the fire-gases, supplying a blast of air to the combustion-hearth and to the generator-chambers below the hearth, maintaining the blast to the hearth strong in the beginning, and then gradually decreasing it, whereby an intense combustion takes place without superfluous air; substantially as described.

3. In a furnace for direct production of iron and steel, the combination with the crucible, the chamber or space above the crucible, the hearth below the crucible, the passage-way leading from said chamber to the hearth, the two sets of zigzag channels partially surrounding the shaft of the furnace, generator-chambers below the hearth, and pipes communicating with said channels, for conducting a blast of air to the hearth and to the generator-chamber; substantially as described.

4. In a furnace for direct production of iron and steel, the combination with the crucible, the chamber above the crucible, the hearth below the crucible, the passage-way leading from said chamber to the hearth, the generator-chamber channels communicating with the hearth and generator-chamber, pipes communicating with said channels, and with a source of compressed air and the chambers B through which compressed outgoing gases are led; substantially as described.

In testimony whereof I have hereto set my hand in the presence of the two subscribing witnesses.

CARL JOHANN LUDWIG OTTO.

Witnesses:
OTTO WOLFF,
HUGO DUMMER.