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BY A. P. C.

J. LOHSE

METHOD OF DIRECTLY PRODUCING PIG IRON AND STEEL

Original Filed Oct. 26, 1940

Serial No. 402,276

2 Sheets-Sheet 1

Fig.1

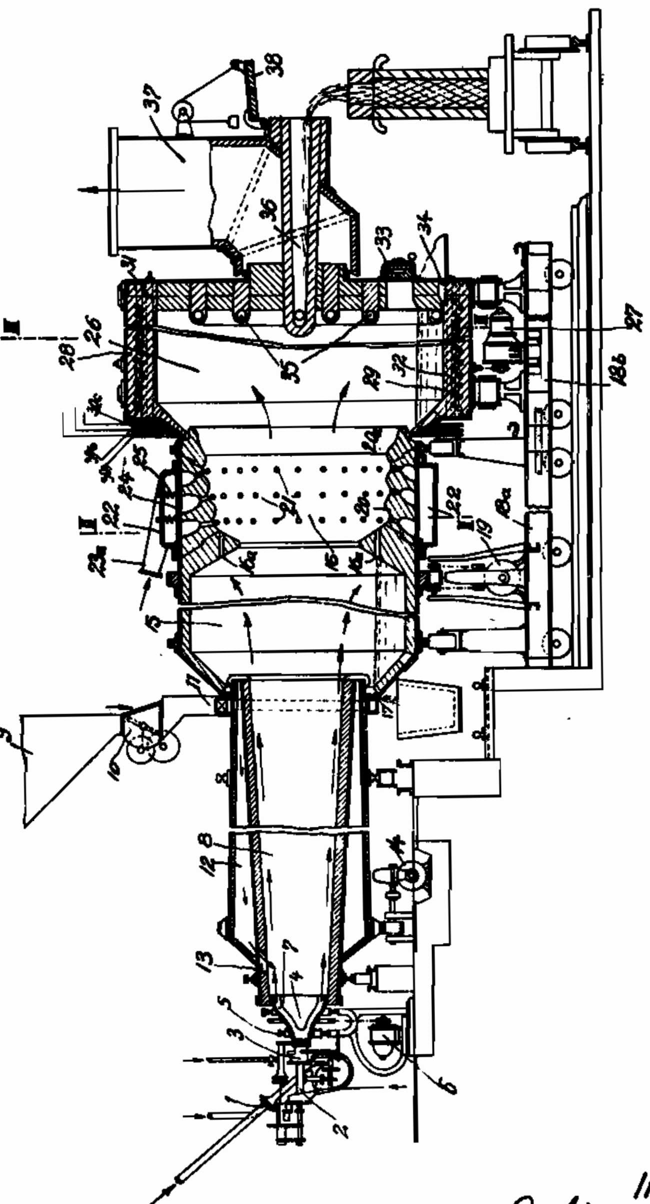

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Fig. 2

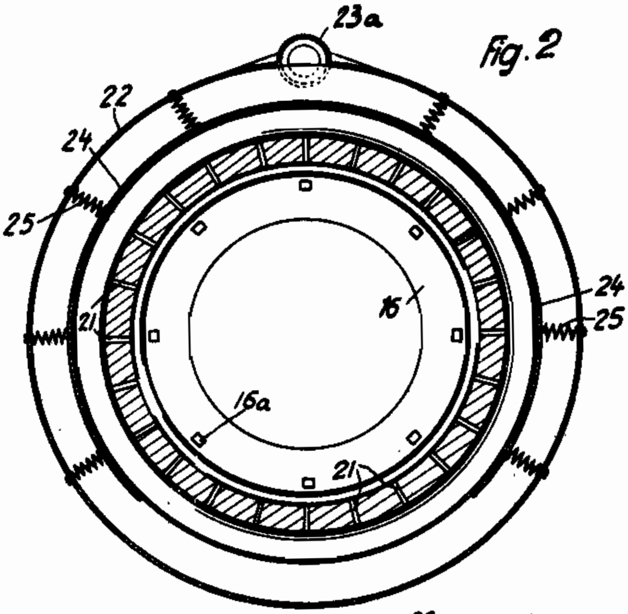
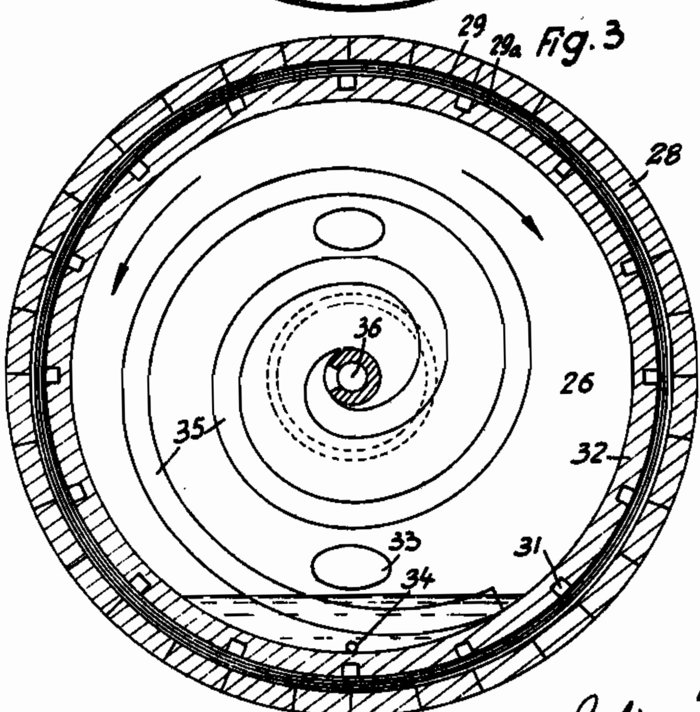


Fig. 3



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ALIEN PROPERTY CUSTODIAN

METHOD OF DIRECTLY PRODUCING PIG IRON AND STEEL

Julius Lohse, Berlin-Wilmersdorf, Germany; vested in the Alien Property Custodian

Application filed July 14, 1941

My present application constitutes a division of my co-pending application Serial No. 363,041 filed October 26th, 1940. The invention disclosed in my present application relates to a method and device for directly producing pig iron and steel from ores, and has for its object to provide improvements according to which a finished product may be made by applying operations that follow one another in a continuous process.

It is known in the art to which my invention appertains, to obtain, within very narrow limits, a certain advantage in the course of the manufacturing process as a whole by providing, for a particular step in the process, a plurality of interconnected rotary furnaces arranged one after another on a common axis to perform some operations under favorable conditions with respect to the utilization of heat. However, as the other phases of the entire process are carried out in the old fashion on hearths disposed in the front or rear of such novel arrangements, these narrowly limited advantages are lost again at the points of transition either by inavoidable cooling effects or old-fashioned working methods.

For example, it is known to desulphurize, dezinc and agglomerate zinciferous iron pyrites in a series of rotary furnaces and at the end of this plant to feed the liquid or pasty metalliferous residue to blast furnaces.

The advantages obtained hereby as to thorough dressing of the material and steady production are, however, partly lost again due to the fact that until the finished product is ready intermittently operating plants of the old type have to be used which are not timed to the steady flow of the preceding unit. Furthermore, in an arrangement of this kind the residue mentioned will necessarily cool down during conveyance to the blast furnace which will therefore be required to make up for the loss of heat involved.

Although it is known during agglomeration of flue dust, fine ores, cement, etc. to adapt the feed of the material to be worked to the working times of the various hearths with the aid of differently shaped and arranged cylindrical rotary kilns, the advantage afforded by this partial measure incorporated with the usual methods is quite slight and subject to the conditions of the subsequent hearths.

The known arrangements are therefore restricted to providing improvements in the preparation of a final product to be completed in plants of the customary type by the interposition of a progressively operating part unit.

The existing arrangement of several cylindrical furnaces of uniform type cannot yield a useful result for the reason that the rotary furnaces provided for each hearth are, from the point of view of thermal economy, disposed in unfavorable mutual relation and fail to insure steadily increasing heating of the material in continuous way in harmony with the continual progress of the treatment. In effect, it just comes to dressing on a long working path which consumes so much heat that the least available for treatment in the subsequent hearths hardly exceeds that required for ordinary sintering. Furthermore, uniform preparation of the melting charge has not been attained notwithstanding the long dressing path.

It is known to preroast and smelt fine charges by blowing them into a stationary or rotary furnace and thereby to better utilize the heat required for dressing. The known arrangements are restricted to finely screened charges and to the use of a screw conveyor for effecting a whirling feed of the fine charge by the low-pressure method, so that in view of the simultaneously supplied fuel, whether oil or coal dust, what is actually happening resembles more a mixing of the material and its dressing agent than a turbulent inter-motion of both. This explains why this blast roasting involves the considerable drawback that owing to the slight turbulence, the cooling action of the furnace wall and the checking of the gas currents due to this effect of the wall a crust will form inside the furnace at some distance from the entrance of the flame. These deposits tend to gradually grow into the cross-sectional area of the furnace to such an extent that finally only a very restricted passage remains which leads from the first blowing zone to the subsequent hearth in the centre of the operating chamber. Blast roasting under the low-pressure method requires therefore bothersome measures to eliminate these drawbacks, and it has been proposed, for instance, to impart to the centrally positioned burners of the blower flames a swinging motion and thereby to direct an oblique heat ray to the wall for removing such crust formed or going to form, by additional heat application.

Even if these defects of known blast roasting methods are removed, there still remains the drawback that all of the heat and the reduction agent can become effective only in connection with finely screened material, and that this heat-consuming low-pressure method leaves no surplus heat for handling also coarser charges fed to the furnace. Coarser material accruing at each grinding operation has therefore either to be reground or, separately from the fine burden, subjected to roasting in the usual furnaces.

My invention eliminates these drawbacks by producing pig iron and steel in a single chamber space and in closely interrelated operations from material prepared by predrying, roasting, sintering, etc., both fine and coarse material being heated and in a reducing flame smelted to form pig iron and slag. While smelting is going on and material accumulates, slag is continually removed and the liquid iron below the skull drawn off in the form of a thin band and, if steel is to be made, fined through an interchangeable converting zone, desulphurized still more and dephosphorized.

By having all operations directly follow one another in the order mentioned and carrying them out in a chamber through which flame heat continuously passes a final effect is insured which is free from losses. According to my invention, each operation in this arrangement is so adjusted and timed to all others that iron may be continuously produced from pretreated coarse and fine charges. From the point of view of both thermal economy and continuous plant operation, one operation is related to the other, so that by the proper adjustment of quantity and speed high quality of the final product is insured. The smelting and refining method according to my invention is initiated by smelting in one or more flames which rotate in a direction oppositely to that of the furnace and thus sweep along the furnace wall, the screened fine stuff being fed to the burner and the coarse material charged directly to the hearth.

The application of a long and continually rotating flame prevents the wall of the furnace from being destroyed by a flame jet having a steady direction and also causes, together with the radiant heat of the furnace, resmelting and removal of caked deposits which tend to be produced centrifugal set up by the rotation of the furnace. Due to the inclination of the furnace, the molten mass slowly moves in the direction of the next operation. In this way, steady discharge of the liquid material is effected without subjecting the furnace wall to excessive stressing in undue form or causing obstructions through cooling and caking deposits. The molten masses accrueing from the furnace walls and the metallic drops produced by the flames are collectors along the deepest line of the incliner furnace and to the thin bath the preheated coarse charge material is directly added, as stated, and is quickly smelting under the triple effect of the action of the flame, heat radiation, and heat transmission from the furnace wall until pig iron and slag are produced in known manner and collected in a special partition.

The liquefied masses continually flowing out of the rotary smelting chamber collect in a subsequent chamber of the rotary furnace plant. Here, the slag is enabled to flow off, and the pig iron is passed in a thin band over a drum until fitted with nozzles where it is blown during its passage and then collects in a connecting rotary refining chamber which may be equipped with special, for instance electric inductive, heating.

From the charge to the finished product the production of pig iron and steel or electric steel proceeds uninterruptedly without heat losses and without requiring interposed conveying operations.

A proposal of the present inventor, which as yet forms no part of prior knowledge, refers to the direct continuous production of copper from sulphide ores by means of one plant comprising a plurality of rotary furnaces serving for preroasting copper ores, a furnace port attached to the preroasters, a rotary roasting drum built onto the furnace port, a rotary nozzle-operated smelting drum, and a rotary heating and refining drum. This plant is applicable merely for continuously roasting and smelting sulphide ores, as stated.

The hitherto described method of producing pig iron and steel or electric steel in one continuous operation is based on proceeding from a pretreated charging material. In further evolution of my invention it is possible to include also the pretreatment of the ores comprising the predrying, roasting, calcining and reducing operations, in the continuous process and thereby to extend the thermal and manufacturing advantages afforded by my process to the necessary preliminary treatment steps enumerated. With this object in view the multi-drum rotary furnace plant on which my process is based is developed so that the interconnected revolving drums are arranged partly in parallel relation and partly on a common axis. The further steps of the process consist in subjecting the ores with the aid of an auxiliary burner in a rotary furnace, to drying, roasting, calcining, then the reduction by the continual addition of coal, conveying the pretreated ores in an uninterrupted stream to the smelting chamber through a closed transition chamber within which any caked portion of the material may be broken up, and then successively smelting it, removing the slag therefrom, refining it, recarburizing it under the action of superheat, and alloying the product if desired. Due to the fact that the heat to be expended for pretreatment in the parallel arranged rotary drum passes through a closed path, particularly in as much as the heat is bound to the solid substances, to the smelting chamber, not only heat losses which otherwise would have to be compensated for within the smelting zone, are avoided but a steady rise in temperature of pig iron is attained, with all the favorable effects upon roasting, calcining, reduction and the rapid dropping out of liquid metal portions from the pretreated ores. In order to separate, at the start, the water vapors developing in the predrying chamber and the carbon dioxide gases produced in the reduction chamber, from the reduced ore, and to prevent them from reacting upon the ore and thus causing reoxidation, provisions are made to remove them at once and to pass them for further utilization of their heat to a waste heat vessel, etc. The arrangement may further be such that below the disintegrator disposed in the closed transition chamber a connecting pipe leads to the coal dust pipe opening into the main burner so as to cause the powdered particles leaving the disintegrator to be directly drawn into the flame by suction effect produced in the main burner. The invention covers also constructional features intended to promote the attainment of optimum results, which features will be disclosed in the following specification.

On the other hand I may use any well-known method for melting the ore charge and causing the molten product to enter a collecting chamber for the removal of the slag, allowing the molten iron to flow into a fining space for a fining treatment, and subjecting it to a further fining treatment if steel is to be made. Although, such a method would not secure all the advantages and favorable results of my present invention, it would already be a decided improvement on the methods hitherto employed for producing iron and steel.

The invention is illustrated by way of example in the accompanying drawing, in which

Fig. 1 shows an axial longitudinal section of a rotary furnace plant for carrying out the method according to my invention;

Figs. 2 and 3 are cross sections along the lines II—II and III—III, respectively, of Fig. 1;

Fig. 4 shows a rotary furnace plant according to my invention as evolved to include the pretreating steps; and

Fig. 5 is a cross section along the line V—V of Fig. 4.

After previous disintegration of the constituents of a calculated charge to a grain size of 25–30 mm. and screening off the fine stuff below 10 mm. the material below 10 mm. is ground in a fine grinding mill, comprising, for instance, a hammer or ring or short tube mill, a blower, air shifter, and motor, to cement fineness and blown to the lateral tube 1 of the burner 2. Having been thoroughly mixed in a burner nozzle 3 with compressed air of 5–6 atmospheres' pressure, and heating oil of 40 atmospheres' pressure, or fuel gas of a pressure of 5–6 atmospheres, the fine material is thrown, for instance, by means of a rapidly revolving worm not shown into the heater 4 running on roller or ball bearings 5 and rotated by means of an electric motor 6. The inside of the rotary jacket 7 of the heater 4 is provided with a highly refractory lining and processes channels like the vanes of a turbine, whereby whirling partial flames are produced each of which passes along the slowly revolving refractory brick lining of the presmelter 8, so that the heat is mainly transmitted by contact, and radiation has only an indirect effect. Both processes produce, however, chemico-physical actions and phenomena within the flame itself, such, for instance, as the escape of water of crystallization, the combustion of the sulphide sulphur to form sulphurous acid, the release of carbonic acid as a result of calcination, the decomposition of carbon monoxide and ash particles, and decomposition of the fuel oil to methane and ethylene, and the reduction of the metals present, since the operation proceeds without excess air. Finally, metal droplets covered by slag form in the flames of the presmelter 8, drop to the inclined bottom thereof and run off.

Simultaneously, the granular material of 30–10 mm. screen size is conveyed from a storage hopper 9 through a pendulum feeder 10 and feeder shovel 11 to a drying and preheating jacket 12 of the presmelter 8, and after dropping into the latter through a wide slot 13, is heated from above and below by the very hot furnace walls and the radiating flames and generally treated in the manner described above, but at the speed of the slowly moving furnace and not at that of the gas stream. The length of the presmelter 8 is adapted to operation at furnace speed, which is facilitated and rendered free from trouble by a regular motor drive 14 and the long flame peculiar to the burner. At the overflow lip of the presmelter 8 the molten masses flow into the second furnace space comprising two sections, viz. a collector and a mixer 15 and a purifying compartment 16, the collector and mixer 15 being of sufficient size and depth to insure sharp separation of slag and pig iron. The slag floats on top and continually flows over the contracted wall edge of the collector 15 into cars which convey the slag to a waste-dump, though it is also possible to provide in known manner for granulation by air or water. A taphole 17 is provided to permit at its stage a rapid discharge of the pig iron to a bed near the furnace, if a portion of the accruing pig iron is to be sold as pigs. The taphole 17 is of importance also in case of needed repairs to provide for quick removal of the accumulated iron prior to moving the members 15 and 16 by means of the travelling platforms 18a, 18b. The pig iron which has been thoroughly heated in the collector 15 and thoroughly mixed due to the rotation of the drum driven by a motor 19, gradually rises to a certain level and flows through channels 16a preferably of square section and provided in the dam stone partition and leading into the fining compartment 16.

The compartment 16 contains a plurality of stones 20 provided with nozzles and also lipped stones 20a. The stones 20 have an inner face corrugated in terrace fashion and an outer bulge, joined together to form a furnace shell, the corrugations and bulges form annular channels which at regular intervals open into a large number of nozzle holes 21. At the point where the nozzle lining is provided, the outer furnace jacket made of strong boiler plate is correspondingly perforated and on its outside turned and ground over a certain width. This rotary surface machined in the manner described is surrounded by a two-part cast iron wind box 22 provided with stuffing boxes 23 and a supply connection 23a for air, air enriched in oxygen, etc. The perforated portion of the outer furnace jacket is covered to the extent of approximately three-fourths of its circumference by a thin resilient steel band 24 which is slightly forced against the rotating furnace jacket underneath by adjustable springs 25. The ring formed by the lipped stones 20a closes up the compartment 16 and guides also the pig iron into the third space 26 in which refining occurs.

The metallurgical operations in the fining space 16 are as follows:

The pig iron containing numerous impurities, as sulphur, phosphorus, carbon, and slag inclusions, flows slowly through the square channels 16a over the annular channels mentioned, arranged one below the other in terrace fashion, in a uniform thin stream and is subjected from below in known manner to the action of a blast of air rich in oxygen which may be supplied to the tuyeres by a compressor of an oxygen plant, not shown. The sulphur content, partly removed already in the presmelter 8, is now completely eliminated through the action of oxygen, and in the same way phosphorus is removed which escapes in gaseous form. The waste gases are utilized in the usual way in an off-heat vessel. As most finely ground lime powder is also blown into the tuyeres in known manner, calcium sulphide or calcium phosphates are formed. The slag together with the decarburized steel floats to the third furnace space 26 and after an electro-thermal treatment during which the last traces of phosphorus and sulphur are removed is discharged as so-called electric slag through a taphole and filled into cars.

The third or refining furnace space 26 into which the steel decarburized in the fining space 16, flows is rotated by a motor 27 and rests with its sets of rollers and turning means on the travelling platform 18b. The travelling platforms 18a, 18b, are interconnected by a coupling pin, so that in case of repairs to be made on the end walls of the chamber 26 or the electro-thermal heating system thereof the chamber may be uncoupled and drawn out as far as required. The refining space 26 possesses a strong sheet metal furnace jacket having a silica brick lining 28 laid on a heat insulating support and provided with grooves. On this silica lining 28 are wound several layers of strong copper rope 29, which are separated from one another by staggered insulating layers. Each copper rope is subdivided into three groups and comprises a plurality of strands made of stronger enamelled copper wires. The ropes represent therefore coils and are connected in layers through embedded copper pins extending through the jacket of the unit 26 to strong copper slip rings 30*a*, 30*b*, 30*c* disposed outside the furnace. Steel briquettes 31 are embedded in a resistance mass 32 which is a poor current conductor, highly refractory and rammed in in sufficient thickness over the copper rope coils. After removal of fastening nuts, the steel briquettes 31 can be easily withdrawn, for repairs or removal, through doors covered with sheet metal. The electric heating system described by way of example represents a high frequency furnace fitted with plated iron cores inserted inside the coils, which is operated at three-phase or alternating current of medium or high frequency. The metal bath is heated from above by the burner gases, from the side by the radiation of the revolving front face of the furnace and from below by the induced bottom currents.

With the aid of this device chemico-metallurgical refining can be performed as in the known induction furnaces with respect to recarburization and the production of alloy steels. Substances required for refining are introduced through a door 33 below which an auxiliary taphole 34 with spout is provided, though a finished charge is usually discharged by turning the furnace from right to left, seen from the front, whereas during the heating and filling turning in the other direction is required, as indicated in Fig. 3. Automatic discharge for pouring, or filling iron molds placed on a casting bogie, is effected for instance by means of a worm 35 built up of highly refractory hollow bricks and inserted in the end wall in the form of an Archimedean spiral. The worm 35 discharges into a conical outlet pipe 36, also consisting of a refractory material and exchangeably arranged in a waste heat connection 37 which does not participate in the rotation. A flap 38 normally closes up the outlet 36. The elbow 37 is preferably connected to a waste heat boiler not shown and equipped with induced draft chimney and flue dust catcher. The casting worm 35 and the discharge pipe 36 are subjected to constant uniform heating so as to avoid harmful elongation. The heating of the furnace space 26 by fuel gases and bottom currents effects a perceptible saving in current compared with all types of known electric furnaces, which saving is due to the arrangement of the three furnace spaces in the manner described to form a unitary structure.

The not inconsiderable amounts of waste heat can be utilized in a boiler and a steam turbodynamo, and a yield of one ton of steam per one ton of steel ingots may be safely calculated upon. This quantity of steel suffices to cover the power requirements of the rotating furnace plant including disintegration, burner operation, supplementary oxygen plant, electro-thermal heating and the operation of travelling platforms and cranes.

The rotary furnace plant shown in Figs. 4 and 5 embraces, in addition to the production of pig iron and steel, the pretreatment of the ores.

The upper furnace drum A serves for pretreating the fine and coarse ores, and the lower directly connected drums B, C and D arranged on a common axis are used for obtaining the finished product. The upper and lower drums are connected by a closed transition chamber E. At the upper end of the drum A an auxiliary burner F and a rotating flame divider G are provided, and the upper end of the lower series of drums is fitted with a rotatable and swingable main burner H. Those parts of this furnace plant serving for the direct production of the finished product from pretreated ores have been described already in connection with Figs. 1–3.

The pretreating drum A is supplied with fine ore from the hopper 41 through the burner F and with coarser material from the hopper 42 through the rotating flame divider G. Due to the action of the flame of the auxiliary burner F, the fine and coarse ores pass into the drying, roasting and calcining zone of a chamber 43 integral with, and leading into, a chamber 44 of enlarged diameter, in which a reducing zone is formed. At the point of transition between these two zones 43 and 44 reduction coal is supplied by a device which, as can be particularly clearly seen in Fig. 5 comprises a helical track 60 connected with the outer circumference of the drum A, opening with a radial orifice outside the drum A and, during rotation thereof, passing through a filling receptacle 61. An opening 62 of the track 60 at the other end lies within the inner wall of the drum A. When the latter revolves in the direction of the arrow, the helical channel 60 on passing through the receptacle 61 picks up reduction coal which, during further rotation of the drum moves through the opposite opening 62 under the ore bed in the drum A, which bed gradually advances from the higher to the lower end of the drum. The length of the reducing chamber 44 is so dimensioned relative to that of the roasting and calcining chamber 43 that a continuous sequence of operations up to the contracted outlet end 45 of the reducing chamber 44 is obtained, the latter opening with interposed sealing means 46, into a closed chamber E. The chamber E is movably supported on rails 47 and is fitted below with a redisintegrator 48 and a down pipe 49 which communicates with the preheating space of the presmelting furnace B through an annular entering member 50 provided with packing means 50*a*. The gases formed in the reduction furnace A and constituting valuable waste heat are guided through a band 51 to the combustion space of a waste heat boiler 52, and the protective arch 51*a* serves for preventing reoxidation of the treated material and insures safe discharge.

The furnace head or port of the drum B supports the main burner H which can be moved so that it will cover the inner wall of the smelting drum B also in axial direction to prevent the formation of deposits. From below the disintegrator 48 a piping 53*a* leads to the coal dust supply piping 53 of the burner H, so that the powdery matter produced in the disintegrator 48, owing to the suction developed in the burner, is directly conveyed in a state of suspension to the flame. The main burner H is secured to the furnace door 54, capable of being lowered and raised, so as to render the furnace head accessible for repairs. The rotary drum B is driven by a separate motor **55** and discharges, under the action of the main burner H, the liquid metal from the pretreated ores, which then passes to the lower end and into the first compartment of the two-compartment drum C whence the slag can be rearwardly removed as indicated in the drawing and the collected pig iron is exposed to the blast in the central portion in a thin band before it enters the refining unit D, in which, by superheating and induced currents, the remaining sulphur and phosphorus, through the addition of quicklime, etc., are separated in the form of electric slag, and recarburization and possibly also alloying may take place. The waste gases developed during these steps and also in the compartments B, C, D pass through a hot blast stove **52***a* arranged in front of the waste heat boiler **52**. The parts C and D are separately driven by a three-phase and tilting motor arrangement **59**, **59***a* and mounted on a travelling platform **59***b* which is used during repairs. The tuyere member C is separately exchangeable to permit renewal of the lining.

Continuity of the process can be attained without difficulty by correspondingly dimensioning the chambers A, B, C, D as to length and imparting properly related speeds to them. Instead of being superposed as shown, the pretreating chamber A may also be disposed on the side or in front of the smelting, fining and refining drums axially fitting into one another. In this case, the transition chamber E would remain; though slightly changed in structure.

JULIUS LOHSE.