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(54) **Furnace for the direct reduction of iron oxides and method for the manufacturing of iron**

(57) A gravitational furnace (10) for the direct reduction of mineral iron, comprising a substantially cylindrical container (11), a reactor (16) arranged in a median zone of the container (11), between a device (12, 13) to feed the mineral iron and a zone (18) to discharge the reduced metal iron. Distribution nozzles (26) are provided in the peripheral wall (14) of the cylinder (11) to introduce reducing gas into the reactor (16). A substantially cylindrical passive element (20) is inserted into the furnace (10) inside the container (11), substantially coaxial with its longitudinal axis (19), to define a substantially annular reaction chamber (17) of the reactor (16). Also the manufacturing of the furnace is disclosed.

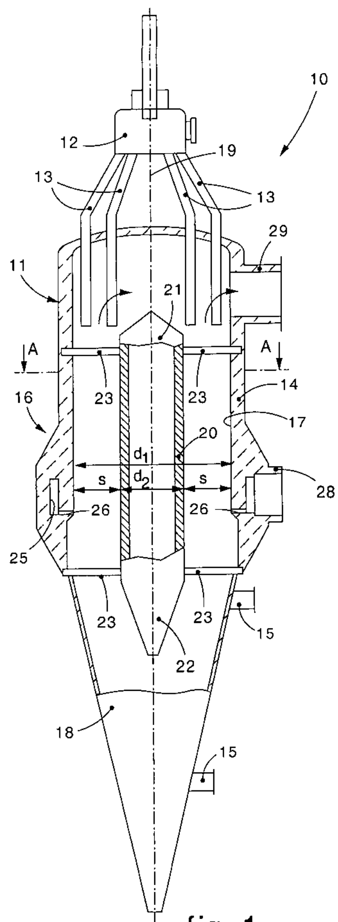

fig. 1

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Description

FIELD OF THE INVENTION

[0001] This invention relates to a furnace for the production of metal iron by means of the direct reduction of mineral iron, where the iron is present in the form of oxides. The furnace is of the gravitational type and comprises a substantially cylindrical vertical container, from the top of which the mineral iron, coarse or in the form of pellets, is introduced. The reduction of the iron oxides fed occurs throughout the cylindrical zone and the reduced iron (DRI) is discharged downwards through a discharge zone, shaped like a truncated cone. The present invention relates also to the method for the manufacturing of the furnace.

BACKGROUND OF THE INVENTION

[0002] The state of the art includes furnaces of the gravitational type, or shaft furnaces, for direct reduction processes comprising an upper loading zone, a central zone, substantially cylindrical or in the shape of a truncated cone, known as a reactor, in which the reduction reaction occurs, means to inject reducing gas into the reactor, and a lower discharge zone, tapered or shaped like a truncated cone, with the taper facing downwards.

[0003] To achieve working conditions which will encourage the homogeneous reduction of the mineral iron fed, it is necessary to optimize inside the shaft the distribution of the reducing gas and the descent of the mineral in the shaft; that is to say, it is necessary to make the surface of contact between the gas and the solid material as large as possible, and to make the time the material stays in the shaft homogeneous.

[0004] In conventional direct reduction furnaces, filled with mineral iron, coarse or in the form of pellets, the reducing gas is normally introduced into the reactor through nozzles arranged in the peripheral walls of the furnace, so that the currents of reducing gas prevalently affect the peripheral zone of the loading column only. Consequently, in every cross-section of the furnace there is a different reducing potential which diminishes the iron reduction process in the whole loading volume.

[0005] In the central zone of the furnace a dead zone is usually created, known as the "dead man", in which the following two factors are present which contribute to reduce the productivity and/or quality of the product:

- poor penetration of the reducing gas;
- high speed of descent of the material which is therefore treated by the gas for a shorter time. This last phenomenon particularly occurs when suitable systems are not used, such as burden feeders which, apart from their anti-sticking function, also have the effect of making the speed of descent of the material homogeneous.

[0006] The uniform distribution of the gas in the different cross-sections of the furnace, at the different heights, depends on the hydraulic resistance of the layer of material loaded and hence on the diameter of the reactor, the method of injection the reducing gas and the upper suction of the gas.

[0007] Any irregularity in the reduction process over the entire volume of the furnace leads to a worsening of the quality of the final production of the directly reduced iron (DRI) and a reduction in productivity.

[0008] These problems limit the diameters of conventional furnaces to values of between about 5 and 6.5 metres, and consequently their productivity.

[0009] To avoid problems connected with the generation of a "dead man", until now the state of the art has considered systems to feed the gas in the central zone of the shaft, as well as in the peripheral zone. The presence of such feed means inside the shaft, on the contrary, constitutes an obstacle to the descent of the solid material. In fact, in the zone where it is deflected, the material is subject to an increase in compression and hence to a greater compactness, which makes it more difficult for the reducing gas to flow through the material and facilitates the sticking phenomenon.

[0010] An example of this type of technology can be found in the patent GB-A-1.522.929, which describes a furnace for the direct reduction of iron, with a double feed of gas, both peripheral and central. In the zone where the section of passage narrows, due to the presence of the central device to feed the gas, the solid material is obliged to divert and this entails peaks of pressure on the material; as the material is compacted, it becomes an obstacle to the flow of reducing gas and encourages the sticking phenomenon.

[0011] Moreover, these are expensive devices, subject to particular wear, given the high working temperatures, and require special maintenance, especially if provided with moving parts.

[0012] Document US-A-4,032,123 discloses a gravity feed shaft furnace for direct reduction of iron ores having cylindrical reducing and cooling zones, a lower tapering discharge zone and an elongated cylindrical member disposed axially within the furnace extending upwardly through the discharge and cooling zones to terminate in the reducing zone. The cylindrical member is a so called active member, used for introducing both hot reducing gas and cooling gas into the center of the reducing zone and of the cooling zone. This known shaft furnace is of a traditional type and the reducing and cooling zones are not dimensioned to optimise the distribution of the reducing gas injected from the peripheral wall of the reducing zone, because additional gas is also injected from the central cylindrical member.

[0013] Document DE-A-2333519 discloses a cylindrical shaft furnace for the direct reduction of mineral iron, which comprises a filling device at the top and a discharge opening at the base. A treatment chamber of ring-like cross-section is disposed between the filling device and the discharge opening and is provided with a vertical tube extending through its central longitudinal axis. Around the treatment chamber there are three ring shaped chambers from which reducing gas is introduced into the treatment chamber. The vertical tube is subdivided into three parts: the central part and the lower part are provided with slits through which the burnt gas is withdrawn from the furnace through a first horizontal conduit and respectively a second horizontal conduit crossing the treatment chamber, while the upper part is provided with a conical upper end and has slits through which additional gas in introduced into the upper part of the treatment chamber. The additional gas reaches the upper part by means of a third horizontal conduit crossing the treatment chamber. This furnace has the disadvantage to be cumbersome and complex and to have three horizontal conduit which cross at different levels the treatment chamber, so creating corresponding obstacles to the correct flowing downstream of the loaded mineral iron. Moreover, this furnace has also the disadvantage that the central vertical tube, which covers substantially the entire height of the treatment chamber, reduces the effective volume of the shaft furnace.

[0014] Document GB-A-752,903 discloses a method and apparatus for the heat treatment of bulk material, in pieces or granulated form, such as chalk, dolomite, cement or ore, wherein a shaft furnace having an annular cross-section shape is provided and wherein the heating gases are supplied from below and discharged from above. This known shaft furnace does not provide the injection of any reducing gas from the peripheral wall and, therefore, does not treat how to optimise the distribution of such a gas within its the annular chamber.

[0015] The present applicant has devised, designed and embodied the furnace for the direct reduction of iron oxides according to the invention to overcome these shortcomings and to increase the productivity of furnaces, at the same time ensuring a uniform distribution of the reducing gas in the loading volume.

SUMMARY OF THE INVENTION

[0016] The furnace to produce metal iron by the direct reduction of iron oxides, and the method for manufacturing the furnace, according to the invention are set forth and characterized in the main claims, while the dependent claims describe other innovative features of the invention.

[0017] The furnace according to the invention is of the gravitational or shaft type, wherein both the material and the gas are fed continuously, so as to create a vertical and gravitational flow of the material and so that the direct reduction of the mineral occurs in the central reactor or reduction zone.

[0018] The reduction furnace is provided with means to feed the mineral iron, arranged above the reduction zone, means to discharge the reduced metal iron, arranged in a tapered zone below the reduction zone and means to distribute the reducing gas arranged peripherally in correspondence with the reactor.

[0019] One purpose of the invention is to achieve a reduction furnace which will permit to increase the hourly production capacity given the same conditions of reducing gas introduced, the same volume and the same surface.

[0020] The technical problem faced and solved by the invention is precisely that of increasing the contact surface between the solid material and the reducing gas, leaving the geometric parameters which influence the direct reduction process unaltered, that is to say: height of the reduction zone, volume of reduction, cross-section of reduction. To clarify the concept better, we shall take into consideration for example a shaft for high DRI productivity (for example 2.5 million tons per year). According to the state of the art, the shaft should have the following characteristics: height of the cylindrical reduction zone about 11 m; diameter of the cylindrical zone of about 8 m; volume of the cylindrical zone about 500 m^3; cross-section of the cylindrical zone about 50 m^2. The conditions of the process in a shaft of this geometry would entail generating a very extensive dead zone, because the limit of penetration of the reducing gas does not exceed 2.5-3 metres.

[0021] The solution proposed with this invention provides that a vertical element of refractory material is disposed in said central dead zone of the shaft, so that the cross-section of the reaction chamber is substantially annular.

[0022] This solution allows to conserve substantially the same reduction volume (about 500 m^3), the same cross-section of reduction (about 50 m^2) and the same height of the reduction zone (about 11 m), slightly increasing the diameter of the shaft (about 9 m) and inserting inside the shaft, and coaxially thereto, a vertical element made of refractory material with a diameter of about 4 m. In this way the depth of penetration of the reducing gas is optimised, that is, about 2.5 m. The vertical element is preferably tubular.

[0023] The thickness of the annular zone thus obtained is equal to, or advantageously less than, the range of the nozzles, arranged peripherally, which distribute the reducing gas.

[0024] Another positive effect given by using this type of shaft geometry is the elimination of a very accentuated parabolic profile of the descending material, which greatly reduces the time for which the material remains in the central zone of the shaft.

[0025] In this way, moreover, the gases are guaranteed to pass in a substantially uniform fashion through the entire thickness of the material, without needing to introduce reducing gas into the center of the furnace.

[0026] With respect to the known apparatus and devices, the furnace according to the present invention has also the following advantages:

- the presence of the central vertical element within the reaction zone not only optimise the distribution of the reducing gas coming from the peripheral wall of the furnace, but also improve the downward flow of the mineral iron;
- the reaction gas-solid mineral is improved and such aspect is not only important for the thermal aspects, but also for the efficiency of the reduction reactions;
- the combination of a peripheral injection of the reducing gas together with the annular profile of the cross-section of the reaction zone results in a very efficient and flexible apparatus in terms of variation of the processing parameters: it is possible to vary the productivity within a good range of work without a significant influence on the efficiency of the furnace;
- the central vertical element has solely a passive function, i.e. it only creates a passive space in the central zone (the so called "dead man") of the furnace, and it is not utilised to inject further gas into the furnace and, consequently, does not require cumbersome transversal pipes which cross the furnace.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027] These and other characteristics of the invention will become clear from the following description of a preferred form of embodiment, given as a non-restrictive example, with reference to the attached drawings wherein:

Fig. 1 is a partially sectioned side view of a furnace for the direct reduction of iron oxides according to the invention;
Fig. 2 is a cross-section from A to A of Fig. 1;
Fig. 3 is a cross-section of a direct reduction furnace, according to the state of the art, with an inner diameter d_3.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0028] With reference to Figs. 1 and 2, a furnace 10 for the direct reduction of iron oxides according to the invention comprises a vertical container 11 having a substantially cylindrical shape and provided with a peripheral wall 14 coaxial to the longitudinal axis 19. The furnace 10 also comprises an upper loading tank 12 from which, through distribution tubes 13, the mineral load, essentially constituted by iron oxides, is able to be introduced.

[0029] The furnace 10 also comprises a median reaction zone, or reactor 16, having an inner diameter d_1, wherein the reduction reaction of the iron oxides takes place, and a lower zone or discharge zone 18, shaped like a truncated cone, with the taper facing downwards. The lower zone 18 is provided with a cooling device 15 of known type.

[0030] A mixture of reducing gas is able to be injected into the reactor 16 through at least a circumferential distributor 25 provided with nozzles 26 disposed in the peripheral wall 14 of the container 11 and connected with a feeding pipe 28.

[0031] According to a characteristic feature of the invention, inside the container 11, coaxial to its longitudinal axis 19, a passive element 20 is inserted. The passive element 20 is substantially cylindrical in shape, is made of refractory material, and define a reaction chamber 17, substantially annular in shape and having a determined transverse width "s".

[0032] The dimension of transverse width "s" is chosen as function of the reducing gas to be injected into the reactor 16, so as to allow a uniform distribution of such a gas from the peripheral wall 14 to the passive element 20. Advantageously the dimension of the transverse width "s" is comprised between about 2.5 and 2.7 m.

[0033] The central element 20 has advantageously a tubular shape, with an outer diameter d_2 which is chosen as function of the inner diameter d_1 of reactor 16, according to the rules disclosed hereinafter, to define a cross-section of the annular reaction chamber 17 which is maximised in proportion to the transverse width "s".

[0034] In order not to impede the downward flow of the mineral iron introduced from above, the upper end 21 of central element 20 is shaped like a truncated cone. Similarly, to facilitate the flow of the reduced iron towards the discharge zone 18, the lower end 22 of the central element 20 is also shaped like a truncated cone.

[0035] Supporting means 23 connect the upper part and the lower part of the central element 20 to the peripheral wall 14 of the container 11. The supporting means 23 are constituted for example by metallic bars having very small transversal dimension, of the order of some centimeter, in order not to impede the downward flow of the mineral iron towards the lower zone 18.

[0036] A discharge pipe 29, possibly provided with a suction device of a conventional type, is provided in correspondence with the upper roof of the furnace 10, to discharge the exhaust gases.

[0037] The mixture of reducing gas and the plant upstream of the pipe 28 can be of any conventional type, for example of the type described in the International Publication Number Wo-00/36156 published on June 22, 2000.

[0038] With reference to Figs. 1, 2 and 3, for whatsoever value of the diameter d_3, which corresponds to the inner diameter of a cylindrical shaft furnace of conventional type, without any central element, it is possible to determine the values of d_1 and d_2 by means of the following system of equations:

$$\begin{cases} \pi \cdot \frac{d_1^2}{4} - \pi \cdot \frac{d_2^2}{4} = \pi \cdot \frac{d_3^2}{4} \\ \frac{d_1}{2} - \frac{d_2}{2} = s \end{cases}$$

[0039] According to a preferential embodiment of the present invention, d_1 is between about 7 and 10 m and d_2 is between about 2 and 4.5 m.

[0040] It is clear that modifications or additions can be made to the furnace 10 for the direct reduction of mineral iron as described heretofore, without departing from the spirit and scope of the invention.

[0041] It is also clear that, although this invention has been described with reference to specific examples, a person of skill in this field shall certainly be able to achieve many other forms of equivalent furnaces, all of which shall come within the field and scope of this invention.

Claims

1. Gravitational furnace for the direct reduction of mineral iron, comprising a substantially cylindrical container (11) having a substantially vertical longitudinal axis (19), feeding means (12, 13) disposed on the upper part of said container (11) to feed the mineral iron, a reactor (16) disposed in a median zone of said container (11), a lower zone (18) to discharge the reduced metal iron, and distribution means (25, 26) disposed on the peripheral wall (14) of said cylindrical container (11) to introduce reducing gas into said reactor (16), the furnace being **characterized in that** a substantially cylindrical passive element (20) is disposed inside said cylindrical container (11), substantially coaxial to said longitudinal axis (19), to define a substantially annular reaction chamber (17) of said reactor (16), wherein the inner diameter (d_1) of said cylindrical container (11) and the outer diameter (d_2) of said cylindrical passive element (20) have values which cause that both the cross-section of said annular reaction chamber (17) is maximised and the distribution of said reducing gas coming from said distribution means (25, 26) is optimised.

2. Furnace as in claim 1, **characterized in that** said passive element (20) is made of refractory material.

3. Furnace as in claim 1, **characterized in that** said passive element (20) is tubular in shape.

4. Furnace as in claim 1, **characterized in that**, so as not to impede the downwards flow of the mineral iron introduced from above, said passive element (20) has an upper end (21) shaped like a truncated cone.

5. Furnace as in claim 1, **characterized in that**, to facilitate the flow of the reduced metal iron towards said discharge zone (18), said passive element (20) has a lower end (22) shaped like a truncated cone.

6. Furnace as in claim 1, **characterized in that** supporting means (23) are provided to connect said passive element (20) to said container (11).

7. Furnace as in claim 1, **characterized in that** said reaction chamber (17) has a diameter (d_1) variable preferably between about 7 and 10 m, that the diameter (d_2) of said passive element (20) is variable preferably between about 2 and 4.5 m, so that the transverse width (s) of said reaction chamber (17) advantageously has a value of between about 2.5 and 2.7 m.

8. A method to manufacture a furnace according to any of the preceding claims, wherein it comprises the step of calculating the inner diameter (d_1) of said cylindrical container (11) and the outer diameter (d_2) of said cylindrical passive element (20), with respect to an diameter (d_3) of a furnace without any central element, by applying the following system of equations:

$$\begin{cases} \pi \cdot \frac{d_1^2}{4} - \pi \cdot \frac{d_2^2}{4} = \pi \cdot \frac{d_3^2}{4} \\ \frac{d_1}{2} - \frac{d_2}{2} = s \end{cases}$$

where s is the transverse width of said reaction chamber (17).

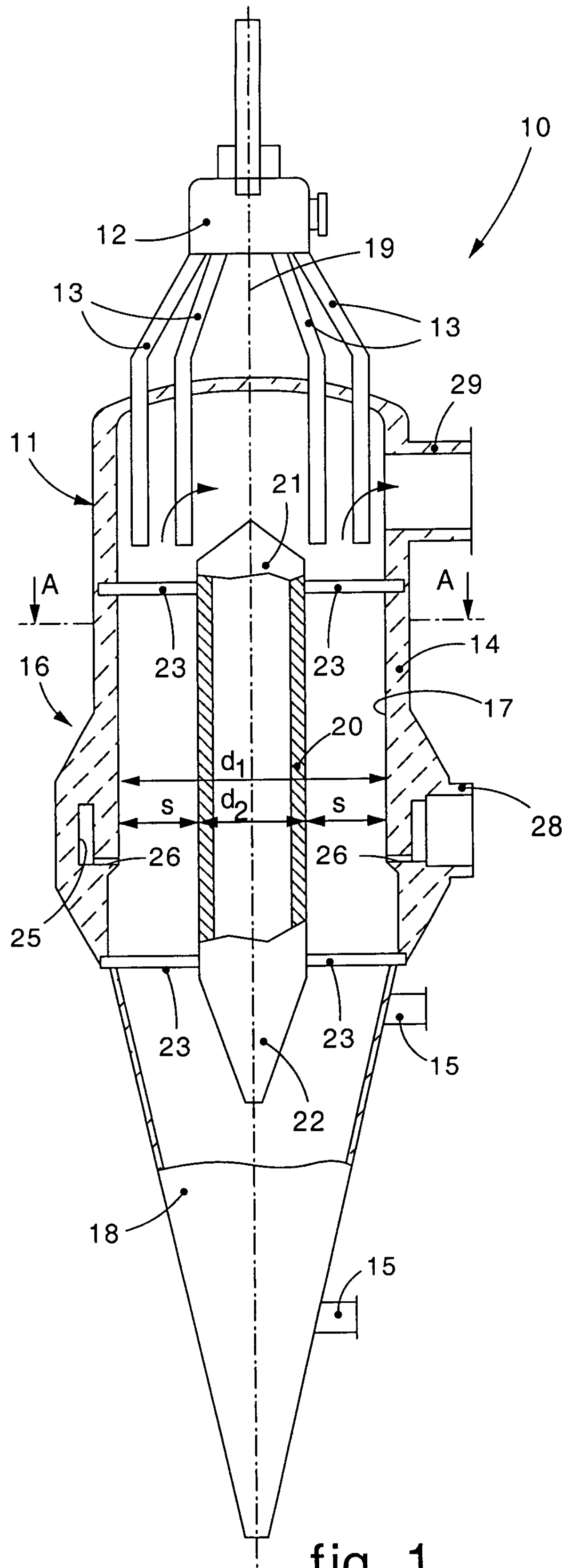

fig. 1

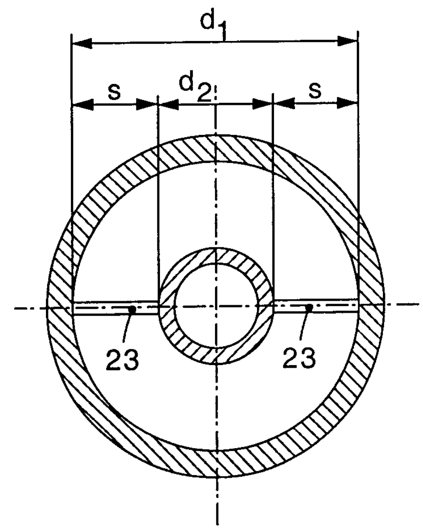

fig. 2

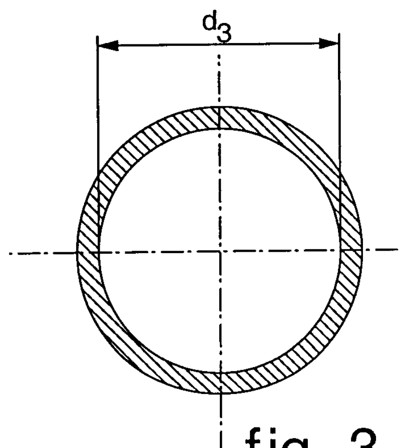

fig. 3

PRIOR ART

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 12 6762

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	19 December 2001	Coulomb, J

CATEGORY OF CITED DOCUMENTS

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