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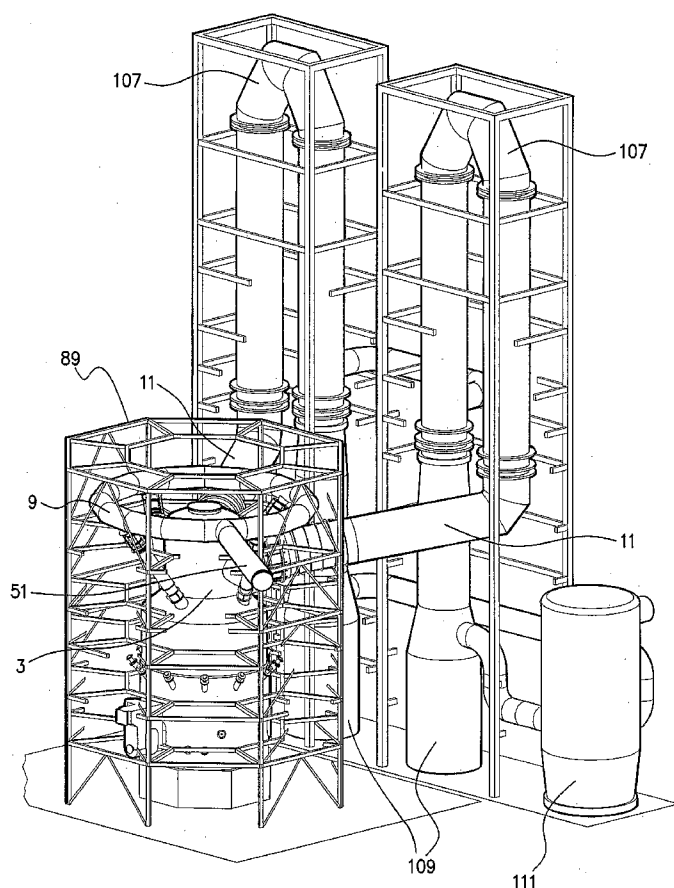
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(54) Title: DIRECT SMELTING PLANT



(57) Abstract: A direct smelting plant for producing molten metal from a metalliferous feed material using a molten bath based direct smelting process is disclosed. The plant includes a plurality of crane access zones that are outboard of a gas delivery main to enable solids injection lances to be removed from and replacement lances to be positioned in openings in a side wall of a direct smelting vessel. The plant also includes a plurality of crane access zones that are inboard of the gas delivery main to enable gas injection lances to be removed from and replacement lances to be positioned in openings in the side wall of the vessel.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DIRECT SMELTING PLANT

TECHNICAL FIELD

5 The present invention relates to a direct smelting plant for producing molten metal from a metalliferous feed material such as ores, partly reduced ores and metal-containing waste streams.

10 A known direct smelting process, which relies principally on a molten bath as a reaction medium, and is generally referred to as the HIs melt process, is described in International Application PCT/AU96/00197 (WO 96/31627) in the name of the applicant. The disclosure in the
15 International application is incorporated herein by cross reference.

 The HIs melt process as described in the International application in the context of producing
20 molten iron includes:

- (a) forming a bath of molten iron and slag in a direct smelting vessel;
- 25 (b) injecting into the bath: (i) a metalliferous feed material, typically iron oxides; and (ii) a solid carbonaceous material, typically coal, which acts as a reductant of the iron oxides and a source of energy; and
- 30 (c) smelting metalliferous feed material to iron in the metal layer.

 The term "smelting" is herein understood to mean thermal processing wherein chemical reactions that reduce
35 metal oxides take place to produce molten metal.

 The HIs melt process also includes post-combusting

reaction gases, such as CO and H₂, released from the bath in the space above the bath with oxygen-containing gas and transferring the heat generated by the post-combustion to the bath to contribute to the thermal energy required to smelt the metalliferous feed materials.

The HIs melt process also includes forming a transition zone above the nominal quiescent surface of the bath in which there is a favourable mass of ascending and thereafter descending droplets or splashes or streams of molten metal and/or slag which provide an effective medium to transfer to the bath the thermal energy generated by post-combusting reaction gases above the bath.

In the HIs melt process the metalliferous feed material and solid carbonaceous material are injected into the molten bath through a number of lances/tuyeres which are inclined to the vertical so as to extend downwardly and inwardly through the side wall of the direct smelting vessel and into a lower region of the vessel so as to deliver at least part of the solid materials into the metal layer in the bottom of the vessel. To promote the post-combustion of reaction gases in the upper part of the vessel, a blast of hot air, which may be oxygen-enriched, is injected into an upper region of the vessel through a downwardly extending hot air injection lance. Offgas resulting from the post-combustion of reaction gases in the vessel is taken away from the upper part of the vessel through an offgas duct. The vessel includes refractory-lined water cooled panels in the side wall and the roof of the vessel, and water is circulated continuously through the panels in a continuous circuit.

The HIs melt process enables large quantities of molten metal, such as molten iron, to be produced by direct smelting in a single compact vessel. In order to achieve this it is necessary to transport large quantities of hot

gas to and from the direct smelting vessel, transport large quantities of the metalliferous feed material, such as iron-containing feed materials, to the vessel, transport large quantities of the molten metal product and slag produced in the process away from the vessel, and circulate large quantities of water through the water cooled panels - all within a relatively confined area. These functions must continue throughout a smelting operation - which desirably extends over at least 12 months. It is also necessary to provide access and handling facilities to enable access to the vessel and lifting of equipment between smelting operations.

A commercial HIs melt direct smelting plant based on a 6 m diameter vessel (internal diameter of refractory hearth) has been constructed at Kwinana, Western Australia. The plant is designed to operate the HIs melt process and produce 800,000 tonnes per year of molten iron in the vessel.

The applicant has now carried out research and development work to design a larger scale commercial HIs melt direct smelting plant to produce in excess of 1 million tonnes per year of molten iron via the HIs melt process.

The applicant has been confronted with a number of problems in scaling up the HIs melt process and has produced an alternate design for a HIs melt direct smelting plant.

The present invention relates to a direct smelting plant that is an alternative design for the commercial HIs melt direct smelting plant mentioned above.

The direct smelting plant of the present invention can also be used to carry out other direct

smelting processes.

DISCLOSURE OF THE INVENTION

5 According to the present invention there is
provides a direct smelting plant for producing molten metal
from a metalliferous feed material using a molten bath
based direct smelting process that includes:

10 (a) a fixed direct smelting vessel to hold a
molten bath of metal and slag and a gas space above the
bath, the vessel including a hearth and a side wall;

 (b) a solids feed assembly to supply solid feed
15 material, including metalliferous feed material and
carbonaceous material, from a solid feed material supply
location away from the vessel into the vessel, the solids
feed assembly including a plurality of solids injection
lances extending through openings in the side wall of the
20 vessel;

 (c) an oxygen-containing gas feed assembly to
supply an oxygen-containing gas from an oxygen-containing
gas supply location away from the vessel into the vessel,
25 the oxygen-containing gas feed assembly including a gas
delivery main and a plurality of gas injection lances
extending through openings in the side wall of the vessel
to inject the oxygen-containing gas supplied via the gas
delivery main into the vessel, the gas delivery main
30 extending at least substantially around the vessel and
spaced away from the vessel;

 (d) an offgas duct assembly to facilitate flow
of offgas from the vessel;

35 (e) a metal tapping assembly to tap molten metal
from the bath during a smelting operation;

(f) a slag tapping assembly to tap slag from the bath during a smelting operation; and

5 (g) a plurality of crane access zones that are outboard of the gas delivery main to enable the solids injection lances to be removed from and replacement lances to be positioned in the openings in the side wall of the vessel.

10

Preferably the gas delivery main is spaced away from the vessel so that there is a clearance between the vessel and the gas delivery main that makes it possible to remove the gas injection lances through the clearance, and
15 the plant includes a plurality of crane access zones that are inboard of the gas delivery main to enable the gas injection lances to be removed from and replacement lances to be positioned in the openings in the side wall of the vessel.

20

Preferably the gas delivery main is located above connections of the gas injection lances to the vessel.

Preferably the gas delivery main is a ring main
25 that defines an endless path for gas flow within the main.

Preferably the gas delivery main is a horseshoe main.

30

Preferably each gas injection lance is arranged to direct a stream of gas downwardly and outwardly of a central core of the vessel.

35

Preferably each gas injection lance is arranged to direct a stream of gas downwardly and outwardly towards the side wall of the vessel.

Preferably each gas injection lance is positioned such that the lance points downwardly into the vessel and is angled in relation to a vertical plane and a radial plane in the vessel so that the direction of flow of a stream of gas from the lance has radial and circumferential components.

Preferably the solids feed assembly includes a plurality of solids injection lances that extend downwardly and inwardly through openings in the side wall of the vessel, and the solids injection lances include a plurality of lances to inject metalliferous material into the vessel and a plurality of lances to inject solid carbonaceous material into the vessel, the metalliferous material injection lances being positioned in pairs around the perimeter of the side wall of the vessel, and a single solid carbonaceous material injection lance being positioned between adjacent pairs of the metalliferous material injection lances.

20

Preferably the solids feed assembly includes a main supply line for each pair of metalliferous injection lances and a pair of branch lines that extend from the main line and are connected to the lances.

25

Preferably the solids feed assembly includes a hot metalliferous feed material injection system for supplying pre-heated metalliferous feed material into the main supply line for each pair of the metalliferous feed material injection lances.

30

Preferably the plant includes a superstructure that supports the gas delivery main.

Preferably the superstructure also includes a plurality of platforms that provide workman access to the vessel at different heights of the vessel.

35

Preferably the offgas duct assembly extends from the upper cylindrical section.

5 Preferably the transition section includes the openings for the gas injection lances and the lances extend through the openings into the vessel.

10 Preferably the lower cylindrical section includes the openings for the solids injection lances, and the lances extend through the openings into the vessel.

15 Preferably the metalliferous material includes iron ore.

 Preferably the carbonaceous material includes coal.

20 According to the present invention there is also provided a direct smelting plant for producing molten metal from a metalliferous feed material using a molten bath based direct smelting process that includes:

25 (a) a fixed direct smelting vessel to hold a molten bath of metal and slag and a gas space above the bath, the vessel including a hearth and a side wall;

30 (b) a solids feed assembly to supply solid feed material, including metalliferous feed material and carbonaceous material, from a solid feed material supply location away from the vessel into the vessel, the solids feed assembly including a plurality of solids injection lances extending through openings in the side wall of the vessel;

35 (c) an oxygen-containing gas feed assembly to supply an oxygen-containing gas from an oxygen-containing

gas supply location away from the vessel into the vessel,
the oxygen-containing gas feed assembly including a gas
delivery main and a plurality of gas injection lances
extending through openings in the side wall of the vessel
5 to inject the oxygen-containing gas supplied via the gas
delivery main into the vessel, the gas delivery main
extending at least substantially around the vessel and
spaced away from the vessel so that there is a clearance
between the vessel and the gas delivery main that makes it
10 possible to remove the gas injection lances through the
clearance;

(d) an offgas duct assembly to facilitate flow
of offgas from the vessel;

15

(e) a metal tapping assembly to tap molten metal
from the bath during a smelting operation;

(f) a slag tapping assembly to tap slag from the
20 bath during a smelting operation; and

(g) a plurality of crane access zones that are
inboard of the gas delivery main to enable the gas
injection lances to be removed from and replacement lances
25 to be positioned in the openings in the side wall of the
vessel..

Preferably the plant further includes cooling
water header pipes for supply of cooling water to the
30 vessel, the cooling water header pipes located above the
gas feed assembly and a plurality of cooling water supply
and return pipes extending between the cooling water
headers and the vessel and distributed about the cooling
water header pipes intermediate the crane access zones
35 positioned inboard of the gas delivery main.

Preferably the cooling water supply and return

Preferably the crane access zones for the solids injection lances are inboard of an outer perimeter of the superstructure.

5

Preferably the offgas duct assembly includes two offgas ducts extending outwardly from the vessel.

Preferably the offgas ducts are of matching diameter.

10

Preferably the offgas ducts are of matching length.

15

Preferably the plant includes two offgas hoods to cool offgas, with one the offgas hood being connected to one the offgas duct.

Preferably each offgas hood is adapted to cool offgas to a temperature of the order of 900-1100°C.

20

Preferably the plant includes a separate offgas scrubber to remove particulates from offgas that is connected to each offgas hood.

25

Preferably the plant includes a single offgas cooler connected to both offgas scrubbers.

Preferably the side wall of the vessel includes:

30

(a) a lower cylindrical section,

(b) an upper cylindrical section that has a smaller diameter than the lower section, and

35

(c) a transition section that interconnects the upper and lower sections.

pipes are distributed about the cooling water header pipes so as to provide, at least in part, one or more external peripheries of the crane access zones positioned inboard of the gas delivery main.

5

Preferably the water supply and return pipes are distributed about the cooling water headers in a plurality of separate zones that are spaced apart from one another.

10

Preferably the cooling water headers extend at least substantially around the vessel.

15

Preferably the cooling water headers are located vertically above and in substantial alignment with the gas delivery main of the gas feed assembly.

20

Preferably the plant further includes a plurality of cooling water headers extending substantially around the vessel, and located at different vertical heights so as to supply water to different areas of the vessel and the headers in substantial alignment with the gas delivery main of the gas feed assembly.

BRIEF DESCRIPTION OF THE DRAWINGS

25

The present invention is described in more detail hereinafter by way of example with reference to the accompanying drawings, of which:

30

Figures 1 and 2 are perspective views from two different directions which illustrates a direct smelting vessel and a part of an off-gas duct system that forms part of one embodiment of a direct smelting plant in accordance with the present invention;

35

Figure 3 is a perspective view of the vessel;

Figure 4 is side elevation of the vessel;

Figure 5 is a side elevation of the vessel which illustrates the layout of refractory bricks in the interior
5 of the vessel;

Figure 6 is a side elevation of the vessel which illustrates the arrangement of solids injection lances and the hot air injection lances of the vessel;
10

Figure 7 is a cross-section along the line A-A in Figure 6;

Figure 8 is a cross-section along the line B-B in
15 Figure 6;

Figure 9 is a diagram that illustrates the arrangement of solids injection lances in the vessel;

Figure 10 is a diagrammatic top plan view of selected components of the vessel that illustrates extraction and insertion envelopes for the solids injection lances and the hot air injection lances from the vessel;
20

Figure 11 is a top plan view of the vessel;
25

Figure 12 is a top plan view of the vessel with the off-gas duct and the hot air blast delivery system removed; and
30

Figure 13 is a top plan view of the vessel showing water cooling headers and supply piping and ; and

Figure 14 is an isometric view of the superstructure that supports that the hot air blast delivery system, the off-gas ducts and the water cooling system.
35

DETAILED DESCRIPTION OF THE EMBODIMENT

5 The direct smelting plant shown in the Figures is suitable particularly for smelting metalliferous material in accordance with the Hismelt process as described in International patent application PCT/AU96/00197 (WO 96/00197).

10 The plant is not confined to smelting metalliferous material in accordance with the Hismelt process.

15 The following description is in the context of smelting iron ore fines to produce molten iron in accordance with the Hismelt process.

20 The present invention is not confined to the production of molten iron and extends to direct smelting any metalliferous material.

25 The following description focuses on a direct smelting vessel of the direct smelting plant and apparatus, such as solids and gas injection lances, that are directly associated with the vessel.

30 The direct smelting plant also includes other apparatus, including apparatus for processing feed materials for the vessel upstream of the vessel and apparatus for processing products (molten metal, molten slag, and offgas) produced in the vessel. Such other apparatus is not described herein in detail because it is not the focus of the present invention but it nevertheless forms part of the plant. Such other apparatus is described
35 in other patent applications and patents in the name of the applicant and the disclosure in these patent applications and patents is incorporated herein by cross-reference.

With reference to the Figures, in the context of the present invention, the main features of the embodiment of the direct smelting plant shown in the Figures are:

5

(a) a fixed direct smelting vessel 3 to contain a molten bath 41 of metal and slag and a gas space 43 above the bath;

10

(b) a solid feed assembly that includes 12 solids injection lances 5a, 5b to supply solid feed material, including metalliferous feed material and carbonaceous material, into the vessel;

15

(c) an oxygen-containing gas feed assembly to supply an oxygen-containing gas to the vessel which includes:

(c)(i) a gas injection assembly in the form of 4 gas injection lances 7 to inject the oxygen-containing gas into the gas space and/or the bath in the vessel; and

(c)(ii) a gas delivery duct assembly that includes a ring main 9 and a plurality of members 49, one associated with each gas injection lance 7, that connect the ring main 9 and the gas injection lances 7 to deliver the oxygen-containing gas, typically air or oxygen-enriched air, to the gas injection lances 7; and

30

(d) an offgas duct assembly that includes two offgas ducts 11 to facilitate flow of offgas from the vessel away from the vessel;

With reference to Figures 1, 2, and 10, it is relevant to note at this point that the direct smelting plant also includes a superstructure 89 formed from steel beams assembled together to define an octagonal-shaped

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outer perimeter 91, an octagonal-shaped inner perimeter 93 and a series of cross-members 95 interconnecting the perimeter beams. The superstructure 89 supports the ring main 9 of the gas delivery duct assembly via hangers (not shown). The superstructure also includes a plurality of platforms (not shown) that provide workman access to the vessel 3 at different heights of the vessel 3.

The vessel 3 includes (a) a hearth that includes a base 21 and sides 23 formed from refractory bricks, (b) a side wall 25 that extends upwardly from the hearth, and (c) a torispherical roof 27. In order to place the size of the vessel 3 into context, a vessel 3 that is designed to produce 2 million tones per year of molten iron requires a hearth diameter (internal) of around 8m.

The side wall 25 of the vessel 3 is formed so that the vessel includes (a) a lower cylindrical section 29, (b) an upper cylindrical section 31 that has a smaller diameter than the lower section 29, and (c) a frusto-conical section 33 that interconnects the two sections 29, 31.

It is evident from the following description and the drawings that the 3 sections 29, 31, 33 of the side wall 25 of the vessel divide the side wall 25 into 3 separate zones. The lower section 29 supports the solids injection lances 5a, 5b. The frusto-conical section 33 supports the gas injection lances 7. Finally, the upper section 33 in effect, is an offgas chamber from which offgas leaves the vessel.

The side wall 25 and the roof 27 of the vessel 3 support a plurality of water-cooled panels (not shown) and the plant includes a cooling water circuit. With reference to Figure 5, the upper section 33 includes single steel panels and the lower section 29 includes double steel

panels. The cooling water circuit supplies water to and removes heated water from the water-cooled panels and thereafter extracts heat from the heated water before returning the water to the water-cooled panels.

5

The frusto-conical section 33 of the side wall 25 of the vessel 3 includes openings 35 for the gas injection lances 7. The lances 7 extend through the openings 35. The lance openings 35 include mounting flanges 37, and the lances 7 are mounted on and supported by the flanges 37. The lance openings 35 are at the same height of the vessel 3 and are positioned at equi-spaced intervals around the perimeter of the side wall 25 of the vessel 3.

15

With reference to Figure 5, in use of the vessel 3 to smelt iron ore fines to produce molten iron in accordance with the Hismelt process, the vessel 3 contains a molten bath 41 of iron and slag which includes a layer (not shown) of molten metal contained in the hearth of the vessel 3 and a layer (not shown) of molten slag on the metal layer 22. The molten bath 41 shown in Figure 5 is under quiescent conditions - i.e. under conditions in which there is no solids and gas injection into the vessel 3. Typically, when the Hismelt process is operating in the vessel 3 to produce 2 million tones per year of molten iron, the vessel 3 contains 500 tonnes of molten iron and 700 tonnes of molten slag.

With reference to Figures 3 and 4, the vessel 3 also includes 2 access doors 45 in the side 23 of the hearth to allow access to the interior of the vessel 11 for re-lining or other maintenance work in the interior of the vessel.

35

The access doors 45 are in the form of steel plates that are welded to the sides 23. When access to the interior of the vessel 3 is required, the plates are cut

away from the side 23 of the hearth and replacement plates are welded in position after the work in the vessel 3 has been completed. The access doors 45 are at the same height of the vessel 3. The access doors 45 are spaced at least
5 90° apart around the circumference of the vessel 3. This spacing makes it possible for refractory wall demolition equipment to extend through the doors 45 into the vessel and demolish a substantial part of the refractories of a refractory-lined side wall while the vessel is hot. In
10 addition, the access doors 45 are sufficiently large, typically 2.5 m in diameter, to allow bob-cat or similar equipment access to the interior of the vessel 3.

With reference to Figure 3, the vessel 3 also
15 includes a similar access door 47 in the roof 27 of the vessel 3 to allow access to the interior of the vessel 11 for re-lining or other maintenance work in the interior of the vessel 3.

20 In use, the four gas injection lances 7 of the gas injection assembly inject an oxygen-enriched hot air blast from a hot gas supply station (not shown) located some distance away from the reduction vessel 11. The hot gas supply station includes a series of hot gas stoves (not
25 shown) and an oxygen plant (not shown) to enable an oxygen-enriched air stream to be passed through the hot gas stoves and into a hot gas delivery duct 51 (Figures 2 and 11) which is connected to the ring main 9. Alternatively, oxygen may be added to an air stream after the air stream
30 has been heated by the stoves.

The purpose of the gas injection lances 7 is to inject a sufficient flow rate of the oxygen-enriched hot air at a sufficient velocity so that the hot air penetrates
35 a fountain, typically an annular fountain, of molten metal and slag that is projected upwardly within the vessel 3 as part of the HIs melt process and the oxygen-enriched hot air

combusts combustible gas, such as carbon dioxide and hydrogen released from the bath, that is in the fountain. Combustion of the combustible gas produces heat that is transferred to the molten bath when the molten metal and slag moves back downwardly into the bath.

The gas injection lances 7 are straight-forward injection lances in terms of basic construction and do not include swirlers for imparting swirl to oxygen-enriched air flowing through the lances. As is indicated above, research work of the applicant found that gas injection lances 7 operating without swirl could achieve comparable performance to lances operating with swirl.

The gas injection lances 7 extend downwardly through the frusto-conical section 33 of the side wall 25 of the vessel 3 into the upper region of the vessel 3. The lances 7 are equi-spaced around the frusto-conical section 33 and are at the same height. The lances 7 are positioned to extend downwardly and outwardly to inject hot air towards the lower section 29 of the side wall 25. It is important to note that it is undesirable that oxygen-containing gas contact the side wall 25 of the vessel - high temperatures generated by combustion at the side wall are undesirable from the viewpoint of vessel life. Consequently, the lances 7 are arranged so that tips 53 of the lances 7 are points on a horizontal circle.

The above-described downward and outward injection of oxygen-containing off-gas is also desirable from the viewpoint of avoiding combustion of reaction gases, such as CO, in a central vertical core of the vessel, generally identified by the numeral 139, in Figure 5, and resultant loss of the heat with offgas from the offgas ducts 11.

As can best be seen in Figure 3, the ring main 9

of the gas delivery duct assembly is a circular duct that is positioned above the vessel 3. As is described above, the ring main 9 is connected to the hot gas delivery duct 51 and receives oxygen-enriched air from that duct 51.

5

The ring main 9 includes 4 outlets 65.

The connection members 49 of the gas delivery duct assembly connect together the ring main 9 and the gas injection lances 7.

10

The hot connection member 49 for each gas injection lance 7 includes a spool 61 that extends from an inlet end of the lance 7 and an expansion joint 63 that is connected at one end to the spool 61 and at the other end to an outlet 65 of the ring main 9.

15

In use, the gas injection lances 7 receive oxygen-enriched hot air flow via the ring main 9 and the connection members 49 that connect the lances 7 to the ring main 9. The ring main 9 delivers the same flow rate of hot air to each lance 7.

20

With reference to Figures 6 and 8, the location of each gas injection lance 7 within the vessel 3 can be established theoretically by:

25

(a) positioning the lance 7 vertically with the tip 53 of the lance 7 in a required position - indicated by the circular icons 55 in Figures 6 and 8 - and then,

30

(b) with the lance tip 53 fixed, pivoting the lance 35° in a vertical plane that intersects the lance tip 53 and is perpendicular to a radial plane that intersects the lance tip 35 and then,

35

(c) with the lance tip 53 fixed, rotating the

lance 30° outwardly towards the radial plane.

The gas injection lances 7 are arranged to be removable from the vessel 3.

5

Specifically, each lance 7 can be extracted by detaching the spool 61 and the expansion joint 63 of the associated connection member 49 from each lance 7 and the ring main 9, thereafter unbolting the lance 7 from the mounting flange 37 of the lance opening 35 in the frusto-conical section 33 of the side wall 25, and thereafter connecting the lance 7 to an overhead crane (not shown) and lifting the lance 7 upwardly from the opening 35.

15

Replacement lances 7 can be inserted into the vessel 3 by the reverse procedure to that described in the preceding paragraph.

The 12 solids injection lances 5a, 5b of the solids feed assembly extend downwardly and inwardly through openings (not shown) in the side wall 25 of the lower section 29 of the side wall 25 of the vessel 3 and into the slag layer (not shown) of the molten bath 41. The lances 5a, 5b are arranged so that the tips of the lances are points of an imaginary horizontal circle. The side wall 25 includes mounting flanges 69 and the lances 5a, 5b are mounted onto and supported by the flanges 69.

With reference to Figures 7 and 9, the solids injection lances 5a, 5b include (a) 8 lances 5a to inject iron ore fines and fluxes into the vessel 3 and (b) 4 lances 5b to inject solid carbonaceous material and fluxes into the vessel 3.

35

The solid materials are entrained in an oxygen-deficient carrier gas. All of the lances 5a, 5b are the same external diameter and are positioned at the same

height of the vessel 3. The lances 5a, 5b are equi-spaced around the circumference of the lower section 29 of the side wall 25 and are arranged so that the iron ore injection lances 5a are arranged in pairs and there is a coal injection lance 5b separating each adjacent pair of iron ore injection lances 5a. The pairing of the iron ore lances 5a to inject hot iron ore into the vessel reduces piping access issues around the vessel.

10 In use, the iron ore injection lances 5a receive hot iron ore fines and fluxes via a hot ore injection system and the coal injection lances 5b receive coal and fluxes via a carbonaceous material injection system during a smelting operation.

15 With reference to Figure 9, the hot ore injection system includes a pre-heater (not shown) to heat the iron ore fines and a hot ore transfer system that includes a series of main supply lines 73 and pairs of branch supply lines 75 for each pair of iron ore injection lances 5a and a supply of carrier gas to transport the hot ore fines in the supply lines 71, 73 and to inject the hot ore fines into the vessel 3 at a temperature of the order of 680°C.

25 With reference to Figure 9, the carbonaceous material/flux injection system includes single supply line 77 for each coal injection lance 5b.

30 The outer diameter of the coal supply lines 75 is less than, typically 40-60% of, the outer diameter of the hot ore branch lines 75. While the internal diameter of the lances 5a, 5b is preferably the same, the need to insulate the hot ore supply lines 75 and the hot ore branch lines 77 significantly increases the outer diameter of the lances. Typically, the hot ore branch lines 75 have the same outer diameter in a range of 400-600mm and the coal supply lines 77 have the same outer diameter in a range of

100-300mm. In one particular example, the hot ore branch lines 75 have an outer diameter of 500mm and the coal supply lines 77 have an outer diameter of 200mm.

5 The solids injection lances 5a, 5b are arranged to be removable from the vessel 3.

 Specifically, the solid feed assembly includes an assembly to support each solids injection lance 5a, 5b
10 during removal of the lance from the vessel and insertion of a replacement lance into the vessel 3. The support assembly for each lance 5a, 5b includes an elongate track (not shown) extending upwardly and outwardly from the side wall 25 of the vessel 3, a carriage (not shown) movable
15 along the track, and a carriage drive (not shown) operable to move the carriage along the track, with the carriage being connectable to the lances 5a, 5b to enable the lance to be supported on the track and moved upwardly and
20 downwardly by operation of the carriage drive and thereby extracted from the vessel 3. The support assembly is described in International applications PCT/2005/001101 and PCT/AU2005/01103 in the name of the applicant and the disclosure in the International applications is
25 incorporated herein by cross-reference.

 As will be evident from the above description, the direct smelting plant accommodates removal and replacement of 16 lances comprising the 4 gas injection lances 7 and the 12 solids injection lances 5a, 5b. The
30 vessel 3 is a relatively compact vessel. This compactness of the vessel 3 and the positions of the ring main 9 and the gas ducts 11 in relation to the vessel 3 places tight space constraints on the removal and replacement of the lances 7, 5a, 5b.

35 With reference to Figure 10, in order to facilitate removal and replacement of the lances 7, 5a, 5b,

the direct smelting plant includes a plurality of vertically extending overhead crane access zones 97a, 97b.

5 The access zones 97a are outboard of the ring main 9 and inboard of the outer perimeter 91 of the superstructure 89. There are 12 access zones 97a in total, corresponding to the 12 solids injection lances 5a, 5b. The access zones 97a enable removal and replacement of the solids injection lances 5a, 5b.

10

The access zones 97b are inboard of the ring main 9. There are 4 access zones 97b in total, corresponding to the 4 gas injection lances 7. The access zones 97b enable removal and replacement of the gas injection lances 7. .

15

The pair of offgas ducts 11 of the offgas duct assembly allow offgas produced in a Hismelt process operating in the vessel 3 to flow from the vessel 3 for downstream processing before being released to the atmosphere.

20

With reference to Figure 13, there is provided a top view of superstructure 89 showing upper cylindrical section 31 of vessel 3, access zones 97b, water cooling supply header 200, water cooling return header 205 along with water cooling supply and return pipes 215.

25

The water cooling supply header 200 and the water cooling return header are each provided in the form of a ring main. Each header 200, 205 sits vertically above and in substantial alignment with the ring main 9 (not shown in the Figure). Water cooling supply and return piping 215 extends between the water cooling supply and return headers 200, 205 and outlets of water cooling panels located on the vessel 3. Four sets 215a, 215b, 215c, 215d of water cooling supply and return piping 215 are distributed around the superstructure 89 and the vessel 3. Each set bridges

30

35

between the headers 200, 205 and the vessel 3 in a discrete region 220a, 220b, 220c, 220d of the superstructure 89. This allows the access zones 97b to extend upwardly between each set 215a, 215b, 215c, 215d of water cooling supply and return piping 215. Some of the water cooling supply and return pipes 215 extend across the face of the vessel 3 from an area of the discrete region 220a, 220b, 220c, 220d, that is adjacent the vessel 3 to various water cooling panel outlets located between the side wall 25 of the vessel 3 and the access zones 97b. In this way it can be seen that the water cooling supply and return pipes 215 define, at least in part, the external periphery of the access zones 97b.

With reference to Figure 14, there is provided an isometric view of the superstructure 89, showing access floors 230 that provide personnel with access to equipment located on the superstructure. The floors 230 have apertures 235 that provide for access zones 97a. A series of water cooling supply and return headers 240 are provided at differing heights on the superstructure (including the headers 200 and 205 referred to in relation to Figure 13 above). The headers 240 are located on the superstructure so as to be in substantial vertical alignment with the ring main 9 of the gas delivery duct assembly. Each header 240 allows for the supply and the return of cooling water to water cooling panels located in an adjacent section of the vessel. Each header 240 is typically a ring main.

Access zones 97a extend upwardly and outwardly from adjacent the vessel 3, between the supply headers 240, to a region of the superstructure 89 external to the supply headers 240. Access zones 97a extend upwardly from the region external to the supply headers 240, passing through the various floors 230 of the superstructure.

As is indicated above, the Hismelt process

preferably operates with air or oxygen-enriched air and therefore generates a substantial volume of offgas and requires relatively large diameter offgas ducts 11.

5 The offgas ducts 11 extend from the upper section 31 of the side wall 25 at an angle of 7° to the horizontal.

 As can best be seen in Figures 11 and 12, the offgas ducts 11 describe a V-shape when viewed from above
10 the vessel 3. The longitudinal axes X of the offgas ducts 11 describe an angle of 66.32° . The offgas ducts are positioned so that the central axes X of the ducts 11 intersect each other and a point 101 on a radial line L that extends from a central vertical axis 105 of the vessel
15 3. In other words, the axes X of the offgas ducts 11 are not radials from the central vertical axis 105 of the vessel 3.

 With reference to Figures 1 and 2, the direct
20 smelting plant includes separate offgas hoods 107 connected to each offgas duct 11 to cool offgas from the vessel 3. The offgas hoods 107 extend vertically upwardly from the outlet ends of the offgas ducts 11. The offgas hoods 107 cool offgas from the vessel 3 via heat exchange with
25 water/steam passing through the hoods to a temperature of the order of $900-1100^\circ\text{C}$.

 With further reference to Figures 1 and 2, the direct smelting plant also includes separate offgas
30 scrubbers 109 connected to each offgas hood 107 to remove particulates from cooled offgas. Additionally, each offgas hood 107 is connected to a flow control valve (not shown) that controls the flow of offgas from the vessel and through the offgas hood 107. The flow control valves may
35 be incorporated with the offgas scrubbers 109.

 With further reference to Figures 1 and 2, the

direct smelting plant also includes a single offgas cooler 111 connected to both offgas scrubbers 109. In use, the offgas cooler 111 receives scrubbed offgas streams from both of the offgas scrubbers 109 and cools the offgas to a
5 temperature of the order of 25-40°C.

In use, the cooled offgas from the offgas cooler 111 is processed as required, for example by being used as a fuel gas in stoves (not shown) or a waste heat boiler
10 (not shown) to recover chemical energy from the offgas, and thereafter released into the atmosphere as a clean offgas.

The direct smelting plant also includes a metal tapping assembly that includes a forehearth 13 to tap
15 molten iron continuously from the vessel 3. Hot metal produced during a smelting operation is discharged from the vessel 3 through the forehearth 13 and a hot metal launder (not shown) connected to the forehearth 13. The outlet end of the hot metal launder is positioned above a hot metal
20 ladle station (not shown) to supply molten metal downwardly to ladles located at the station.

The direct smelting plant also includes an end metal tapping assembly to tap molten iron from the vessel 3
25 at the end of a smelting operation out of the lower part of the vessel 3 and to transport the molten iron away from the vessel 3. The end metal tapping assembly includes a plurality of metal end tap holes 15 in the vessel 3.

30 The direct smelting plant also includes a slag tapping assembly to tap molten slag from the vessel 3 periodically from the lower part of the vessel and to transport the slag away from the vessel 3 during a smelting operation. The slag tapping assembly includes a plurality
35 of slag notches 17 in the vessel 3.

The direct smelting plant also includes a slag

end tapping assembly to drain slag from the vessel 3 at the end of a smelting operation. The slag end tapping assembly includes a plurality of slag tap holes 19 in the vessel 3.

5 In a smelting operation in accordance with the Hismelt process, iron ore fines and a suitable carrier gas and coal and a suitable carrier gas are injected into the molten bath through the lances 5a, 5b. The momentum of the solid materials and the carrier gases causes the solid
10 materials to penetrate the metal layer of the molten bath 41. The coal is devolatilised and thereby produces gas in the metal layer. Carbon partially dissolves in the metal and partially remains as solid carbon.

15 The iron ore fines are smelted to molten iron and the smelting reaction generates carbon monoxide. Molten iron is removed continuously from the vessel 3 via the forehearth 13.

20 Molten slag is removed periodically from the vessel 3 via the slag notches 17.

 The gases that are transported into the metal layer and generated by devolatilisation and smelting
25 reactions produce significant buoyancy uplift of molten metal, solid carbon and slag (drawn into the metal layer as a consequence of solid/gas/injection) from the metal layer which generates upward movement of splashes, droplets and streams of molten metal and slag, and these splashes,
30 droplets and streams entrain slag as they move through the slag layer. The buoyancy uplift of molten metal, solid carbon and slag causes substantial agitation of the slag layer, with the result that the slag layer expands in volume. In addition, the upward movement of splashes,
35 droplets and streams of molten metal and slag - caused by buoyancy uplift of molten metal, solid carbon and slag - extend into the space above the molten bath and forms the

above-described fountain.

Injection of the oxygen-containing gas into the fountain via the gas injection lances 7 post-combusts
5 reaction gases, such as carbon monoxide and hydrogen, in the vessel 3. Heat generated by the post combustion is transferred to the molten bath when molten material falls back into the bath.

10 Offgas resulting from the post-combustion of reaction gases in the vessel 3 is taken away from the vessel 3 through the offgas ducts 11.

Many modifications may be made to the embodiment
15 of the present invention described above without departing from the spirit and scope of the invention.

By way of example, whilst the embodiment described above includes 2 offgas ducts 11, the present
20 invention is not limited to this number of offgas ducts 11 and extends to any suitable number of offgas ducts 11.

In addition, whilst the embodiment described above includes a ring main 9 to deliver the oxygen-
25 containing gas to the gas injection lances 7, the present invention is not limited to this arrangement and extends to any suitable gas delivery assembly.

In addition, whilst the embodiment described above includes 4 gas injection lances 7, the present
30 invention is not limited to number and the arrangement of the lances 7 and extends to any suitable number and arrangement of the lances 7.

35 In addition, whilst the embodiment described above includes 12 solids injection lances 5a, 5b, with 8 lances 5a being iron ore injection lances arranged in pairs

and the remaining 4 lances 5b being coal injection lances, the present invention is not limited to this number and arrangement of the lances 5a, 5b.

- 5 In addition, whilst the embodiment described above includes a forehearh 13 to tap molten iron continuously from the vessel 3, the present invention is not limited to the use of the forehearth and to continuous tapping of molten iron.

CLAIMS

5 1. A direct smelting plant for producing molten metal from a metalliferous feed material using a molten bath based direct smelting process that includes:

10 (a) a fixed direct smelting vessel to hold a molten bath of metal and slag and a gas space above the bath, the vessel including a hearth and a side wall;

15 (b) a solids feed assembly to supply solid feed material, including metalliferous feed material and carbonaceous material, from a solid feed material supply location away from the vessel into the vessel, the solids feed assembly including a plurality of solids injection lances extending through openings in the side wall of the vessel;

20 (c) an oxygen-containing gas feed assembly to supply an oxygen-containing gas from an oxygen-containing gas supply location away from the vessel into the vessel, the oxygen-containing gas feed assembly including a gas delivery main and a plurality of gas injection lances
25 extending through openings in the side wall of the vessel to inject the oxygen-containing gas supplied via the gas delivery main into the vessel, the gas delivery main extending at least substantially around the vessel and
30 spaced away from the vessel;

(d) an offgas duct assembly to facilitate flow of offgas from the vessel;

35 (e) a metal tapping assembly to tap molten metal from the bath during a smelting operation;

(f) a slag tapping assembly to tap slag from the bath during a smelting operation; and

5 (g) a plurality of crane access zones that are outboard of the gas delivery main to enable the solids injection lances to be removed from and replacement lances to be positioned in the openings in the side wall of the vessel.

10 2. The plant defined in claim 1 wherein the gas delivery main is spaced away from the vessel so that there is a clearance between the vessel and the gas delivery main that makes it possible to remove the gas injection lances through the clearance, and the plant includes a plurality
15 of crane access zones that are inboard of the gas delivery main to enable the gas injection lances to be removed from and replacement lances to be positioned in the openings in the side wall of the vessel.

20 3. The plant defined in claim 1 or claim 2 wherein the gas delivery main is located above connections of the gas injection lances to the vessel.

4. The plant defined in any one of the preceding
25 claims wherein the gas delivery main is a ring main that defines an endless path for gas flow within the main.

5. The plant defined in claim 1 or claim 2 wherein the gas delivery main is a horseshoe main.

30

6. The plant defined in any one of the preceding claims wherein each gas injection lance is arranged to direct a stream of gas downwardly and outwardly of a central core of the vessel.

35

7. The plant defined in any one of the preceding claims wherein each gas injection lance is arranged to

direct a stream of gas downwardly and outwardly towards the side wall of the vessel.

8. The plant defined in any one of the preceding
5 claims wherein each gas injection lance is positioned such that the lance points downwardly into the vessel and is angled in relation to a vertical plane and a radial plane in the vessel so that the direction of flow of a stream of gas from the lance has radial and circumferential
10 components.

9. The plant defined in any one of the preceding claims wherein the solids feed assembly includes a plurality of solids injection lances that extend downwardly
15 and inwardly through openings in the side wall of the vessel, and the solids injection lances include a plurality of lances to inject metalliferous material into the vessel and a plurality of lances to inject solid carbonaceous material into the vessel, the metalliferous material
20 injection lances being positioned in pairs around the perimeter of the side wall of the vessel, and a single solid carbonaceous material injection lance being positioned between adjacent pairs of the metalliferous material injection lances.

25
10. The plant defined in claim 9 wherein the solids feed assembly includes a main supply line for each pair of metalliferous injection lances and a pair of branch lines that extend from the main line and are connected to the
30 lances.

11. The plant defined in claim 10 wherein the solids feed assembly includes a hot metalliferous feed material injection system for supplying pre-heated metalliferous
35 feed material into the main supply line for each pair of the metalliferous feed material injection lances.

12. The plant defined in any one of the preceding claims includes a superstructure that supports the gas delivery main.
- 5 13. The plant defined in claim 12 wherein the superstructure also includes a plurality of platforms that provide workman access to the vessel at different heights of the vessel.
- 10 14. The plant defined in claim 12 or claim 13 wherein the crane access zones for the solids injection lances are inboard of an outer perimeter of the superstructure.
- 15 15. The plant defined in any one of the preceding claims wherein the offgas duct assembly includes two offgas ducts extending outwardly from the vessel.
- 20 16. The plant defined in claim 15 wherein the offgas ducts are of matching diameter.
17. The plant defined in claim 15 or claim 16 wherein the offgas ducts are of matching length.
- 25 18. The plant defined in any one of claims 15 to 17 includes two offgas hoods to cool offgas, with one the offgas hood being connected to one the offgas duct.
- 30 19. The plant defined in claim 18 wherein each offgas hood is adapted to cool offgas to a temperature of the order of 900-1100°C.
- 35 20. The plant defined in claim 18 or claim 19 includes a separate offgas scrubber to remove particulates from offgas that is connected to each offgas hood.
21. The plant defined in claim 18 or claim 19 includes a single offgas cooler connected to both offgas

scrubbers.

22. The plant defined in any one of the preceding claims wherein the side wall of the vessel includes:

5

(a) a lower cylindrical section,

(b) an upper cylindrical section that has a smaller diameter than the lower section, and

10

(c) a transition section that interconnects the upper and lower sections.

23. The plant defined in claim 22 wherein the offgas duct assembly extends from the upper cylindrical section.

15

24. The plant defined in claim 22 or claim 23 wherein the transition section includes the openings for the gas injection lances and the lances extend through the openings into the vessel.

20

25. The plant defined in any one of claims 22 to 24 wherein the lower cylindrical section includes the openings for the solids injection lances, and the lances extend through the openings into the vessel.

25

26. The plant defined in any one of the preceding claims wherein the metalliferous material includes iron ore.

30

27. The plant defined in any one of the preceding claims wherein the carbonaceous material includes coal.

28. A direct smelting plant for producing molten metal from a metalliferous feed material using a molten bath based direct smelting process that includes:

35

(a) a fixed direct smelting vessel to hold a molten bath of metal and slag and a gas space above the bath, the vessel including a hearth and a side wall;

5 (b) a solids feed assembly to supply solid feed material, including metalliferous feed material and carbonaceous material, from a solid feed material supply location away from the vessel into the vessel, the solids feed assembly including a plurality of solids injection
10 lances extending through openings in the side wall of the vessel;

(c) an oxygen-containing gas feed assembly to supply an oxygen-containing gas from an oxygen-containing
15 gas supply location away from the vessel into the vessel, the oxygen-containing gas feed assembly including a gas delivery main and a plurality of gas injection lances extending through openings in the side wall of the vessel to inject the oxygen-containing gas supplied via the gas
20 delivery main into the vessel, the gas delivery main extending at least substantially around the vessel and spaced away from the vessel so that there is a clearance between the vessel and the gas delivery main that makes it possible to remove the gas injection lances through the
25 clearance;

(d) an offgas duct assembly to facilitate flow of offgas from the vessel;

30 (e) a metal tapping assembly to tap molten metal from the bath during a smelting operation;

(f) a slag tapping assembly to tap slag from the bath during a smelting operation; and

35

(g) a plurality of crane access zones that are inboard of the gas delivery main to enable the gas

injection lances to be removed from and replacement lances to be positioned in the openings in the side wall of the vessel..

5 29. The plant defined in any one of the preceding claims further including cooling water header pipes for supply of cooling water to the vessel, the cooling water header pipes located above the gas feed assembly and a plurality of cooling water supply and return pipes
10 extending between the cooling water headers and the vessel and distributed about the cooling water header pipes intermediate the crane access zones positioned inboard of the gas delivery main.

15 30. The plant defined in claim 29 wherein the cooling water supply and return pipes are distributed about the cooling water header pipes so as to provide, at least in part, one or more external peripheries of the crane access zones positioned inboard of the gas delivery main.

20 31. The plant defined in any one of claims 29 or 30 wherein the water supply and return pipes are distributed about the cooling water headers in a plurality of separate zones that are spaced apart from one another.

25 32. The plant defined in any one of claims 29, 30 or 31 wherein the cooling water headers extending at least substantially around the vessel.

30 33. The plant defined in 32 wherein the cooling water headers are located vertically above and in substantial alignment with the gas delivery main of the gas feed assembly.

35 33. The plant defined in any one of claims 29 to 32 and further including a plurality of cooling water headers extending substantially around the vessel, and located at

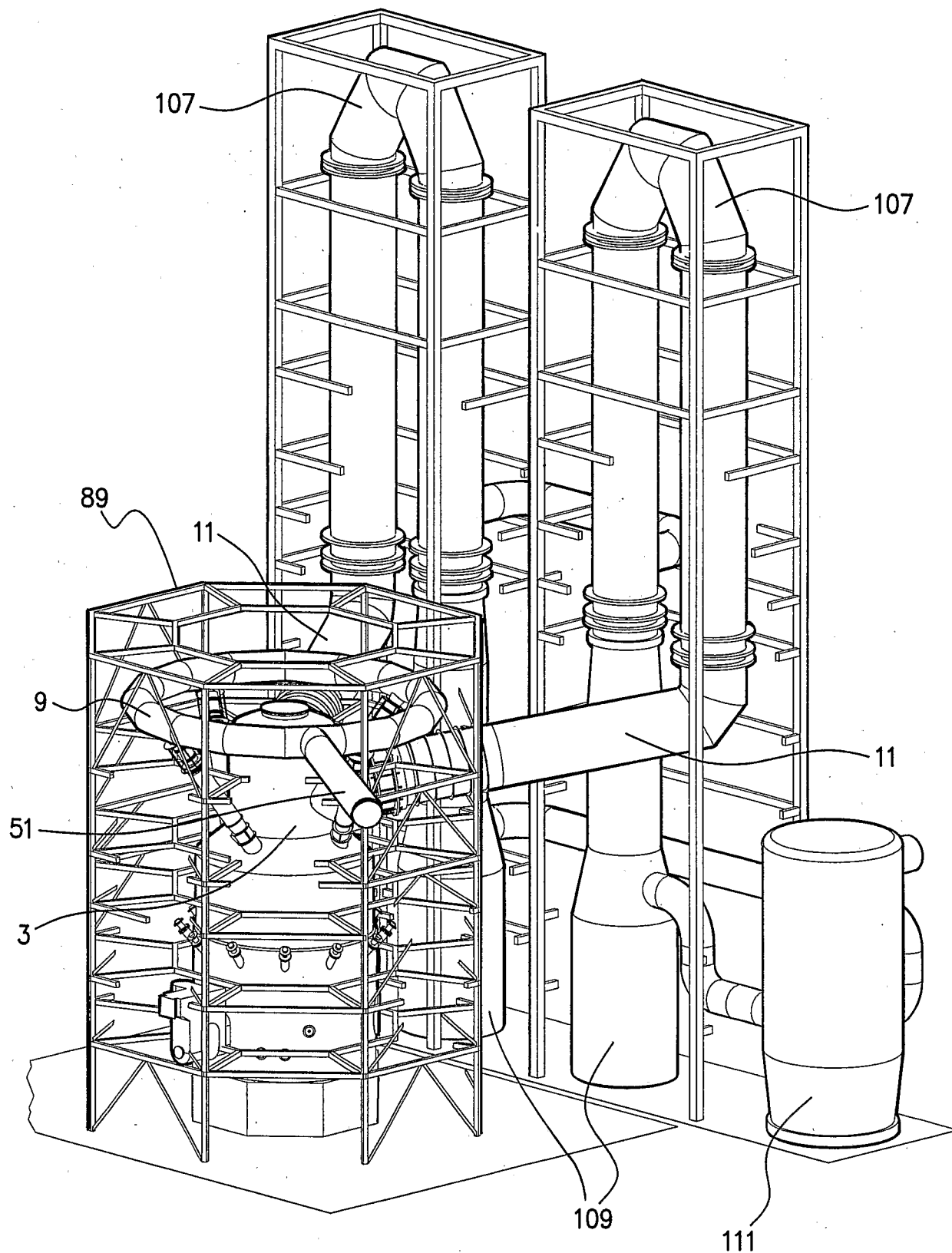
different vertical heights so as to supply water to different areas of the vessel and the headers in substantial alignment with the gas delivery main of the gas feed assembly.

5

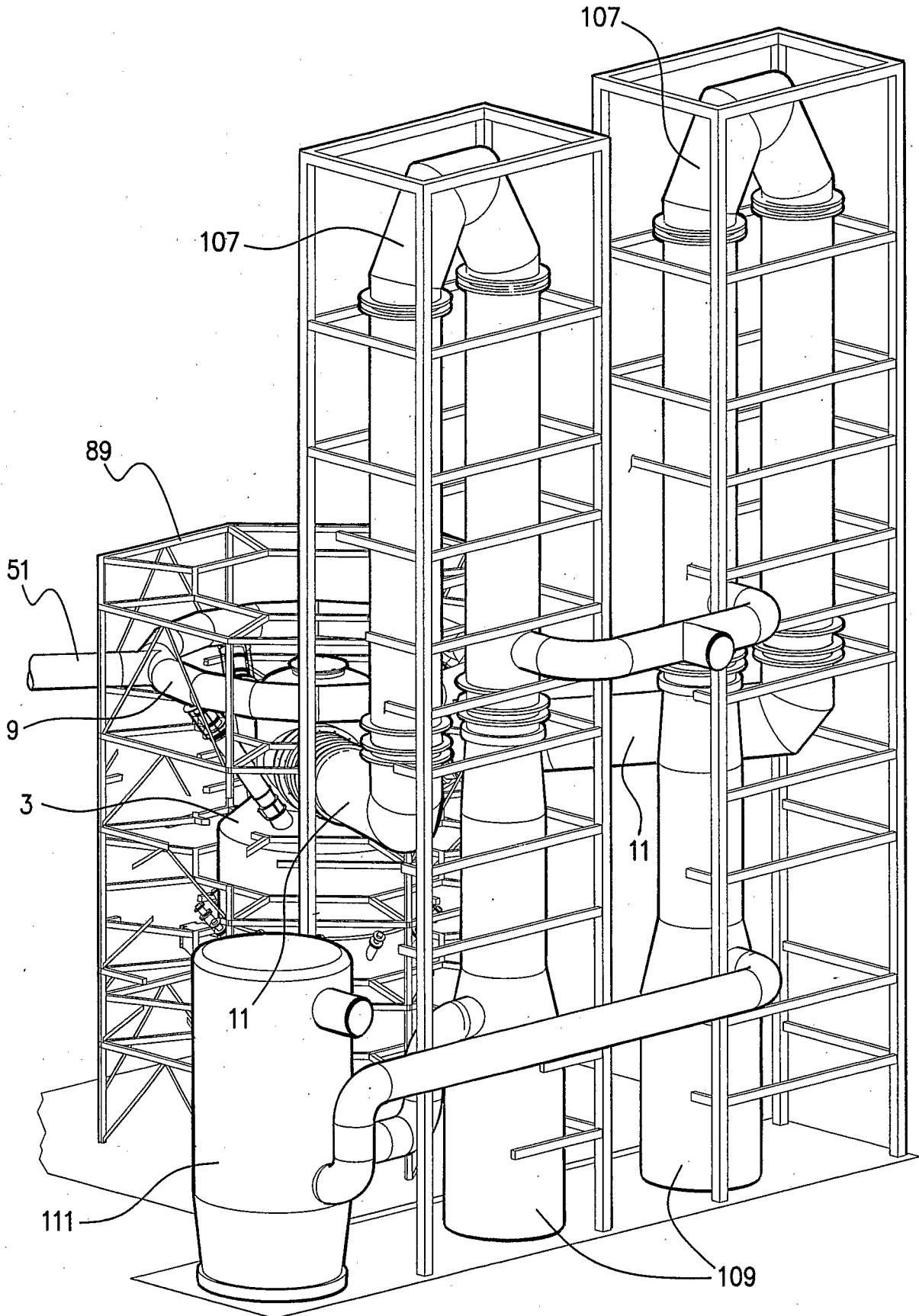
34. The plant defined in any one of claims 29 to 33 further including a plurality of crane access zones that are outboard of the gas delivery main to enable the solids injection lances to be removed from and replacement lances to be positioned in the openings in the side wall of the vessel.

10

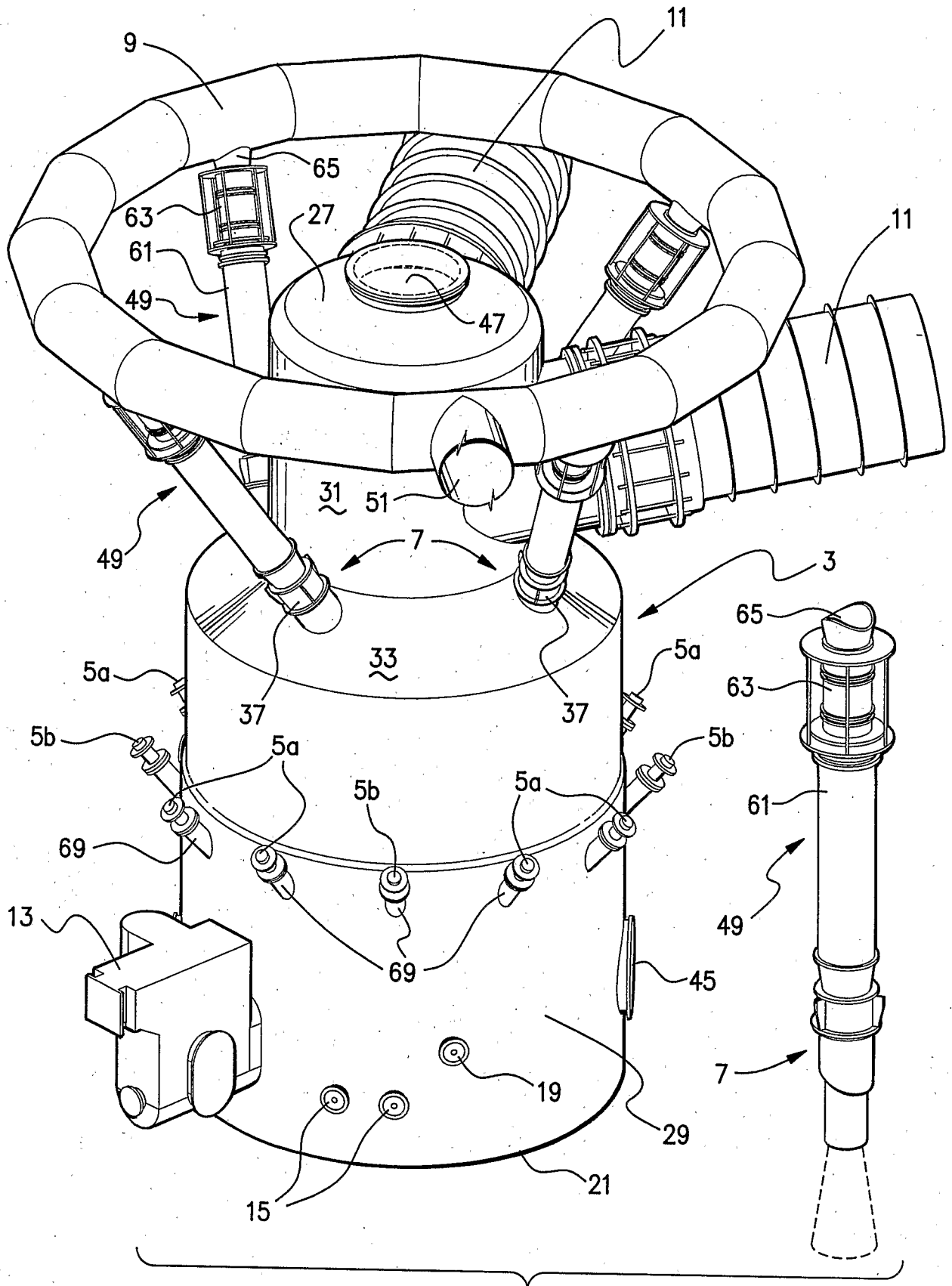
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**FIG. 1**

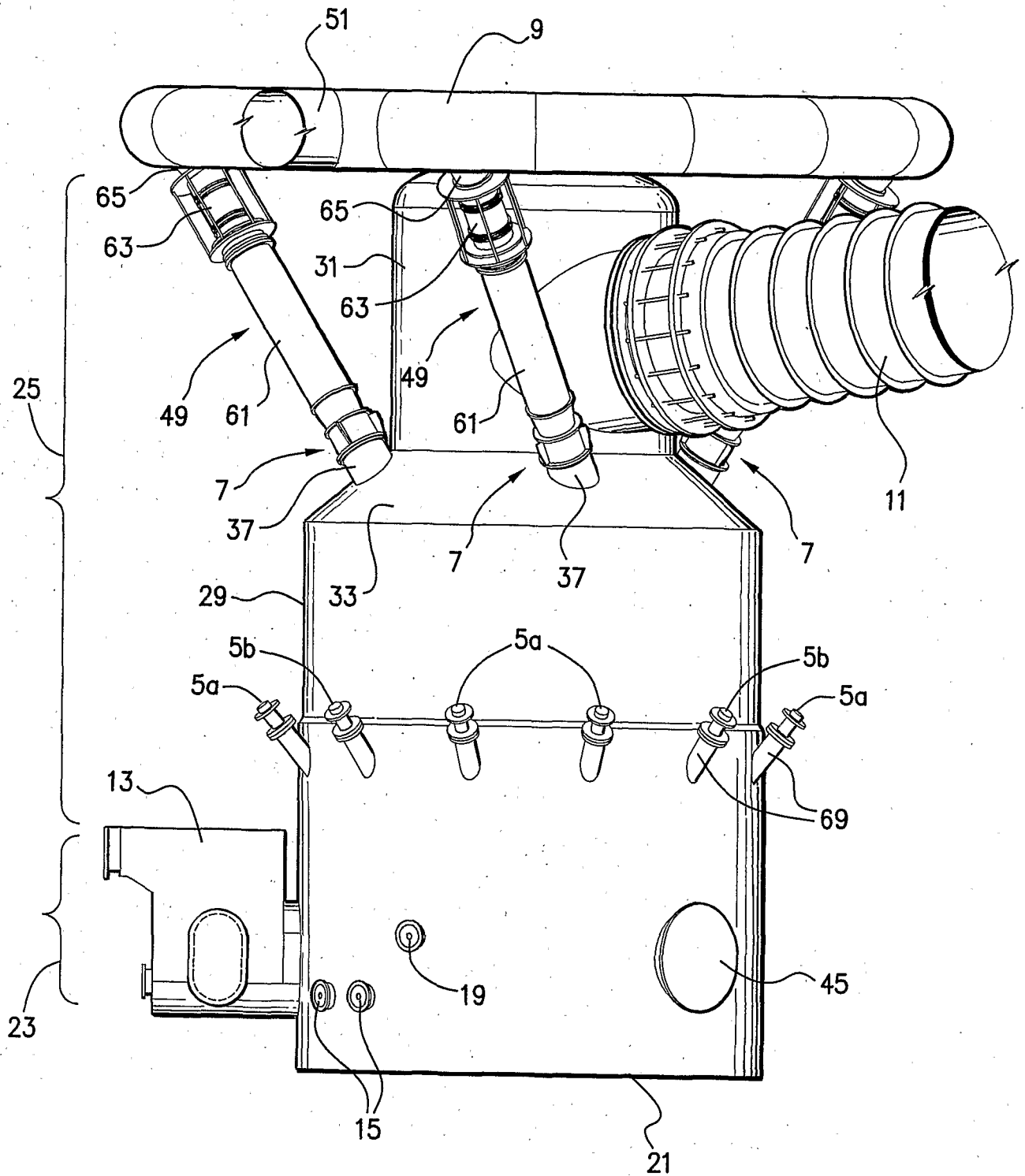
2/13

**FIG. 2**

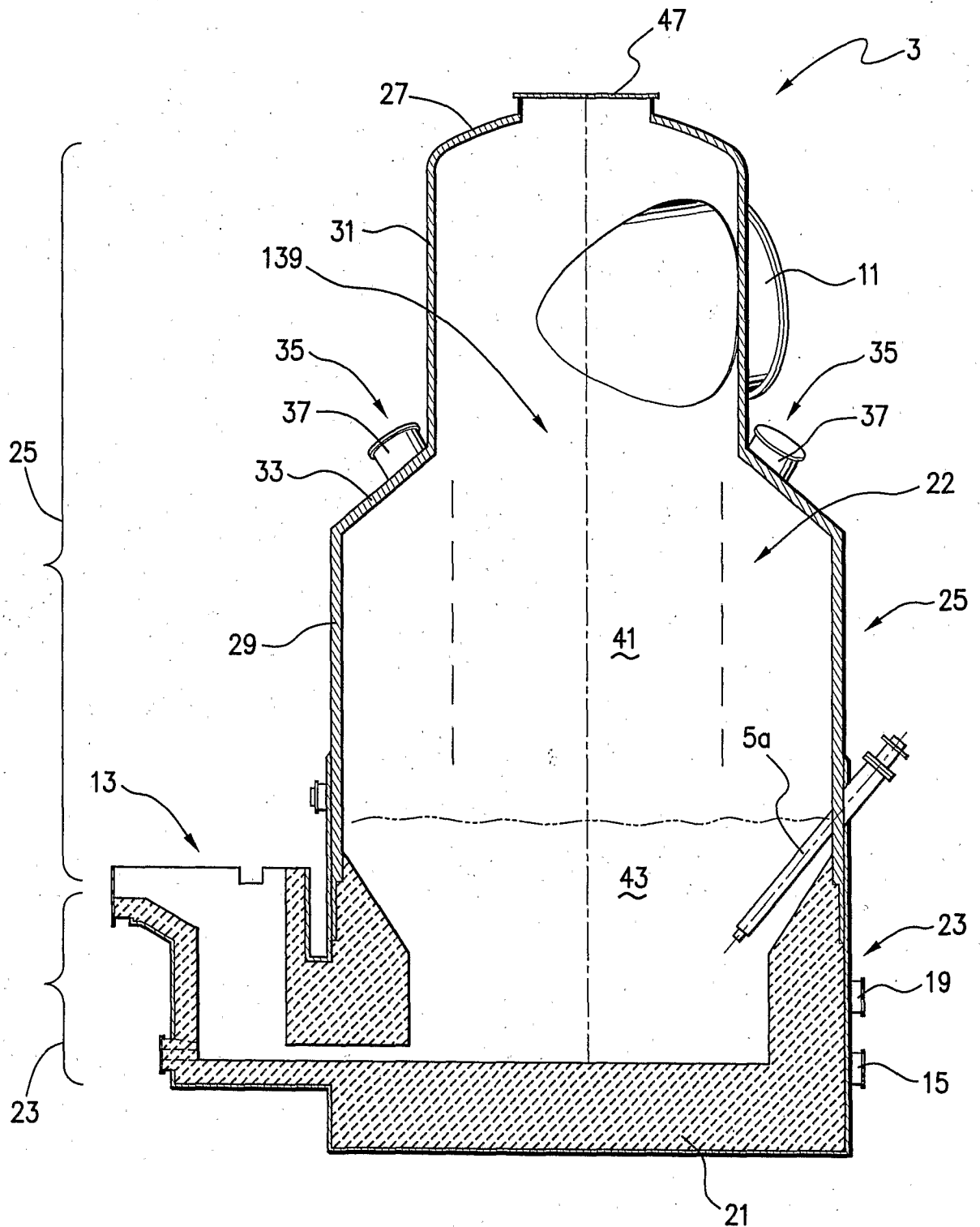
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**FIG. 3**

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**FIG. 4**

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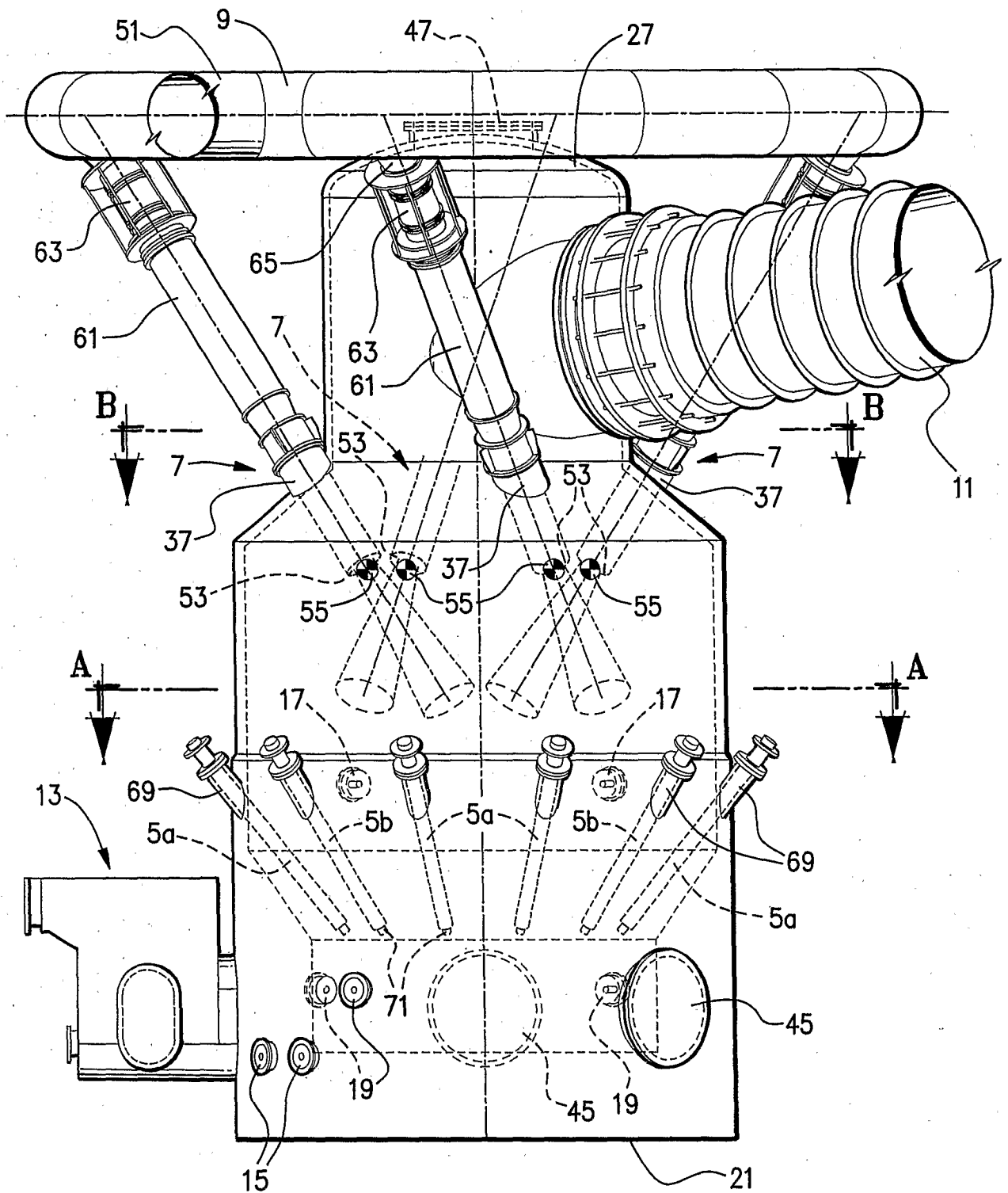
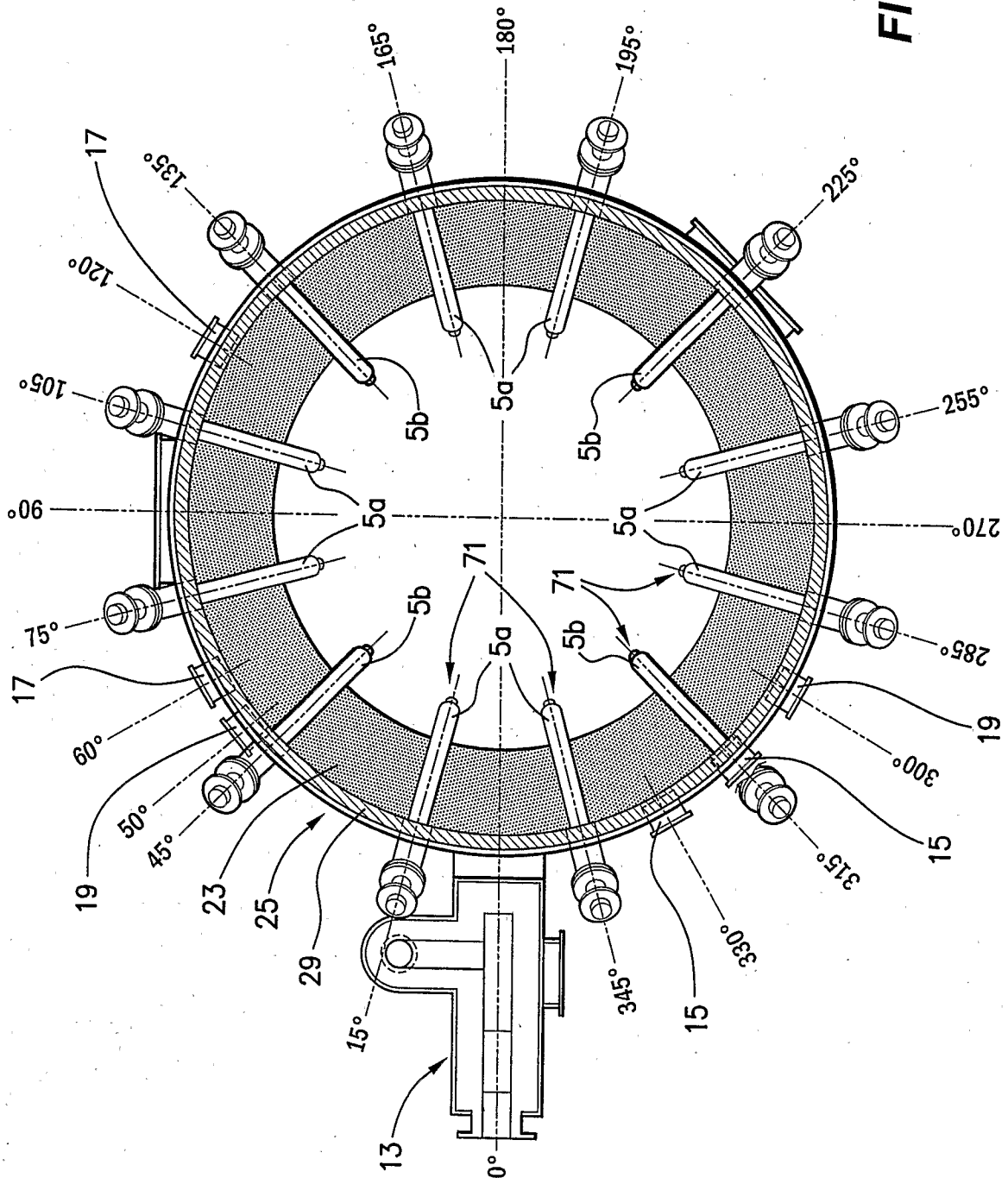
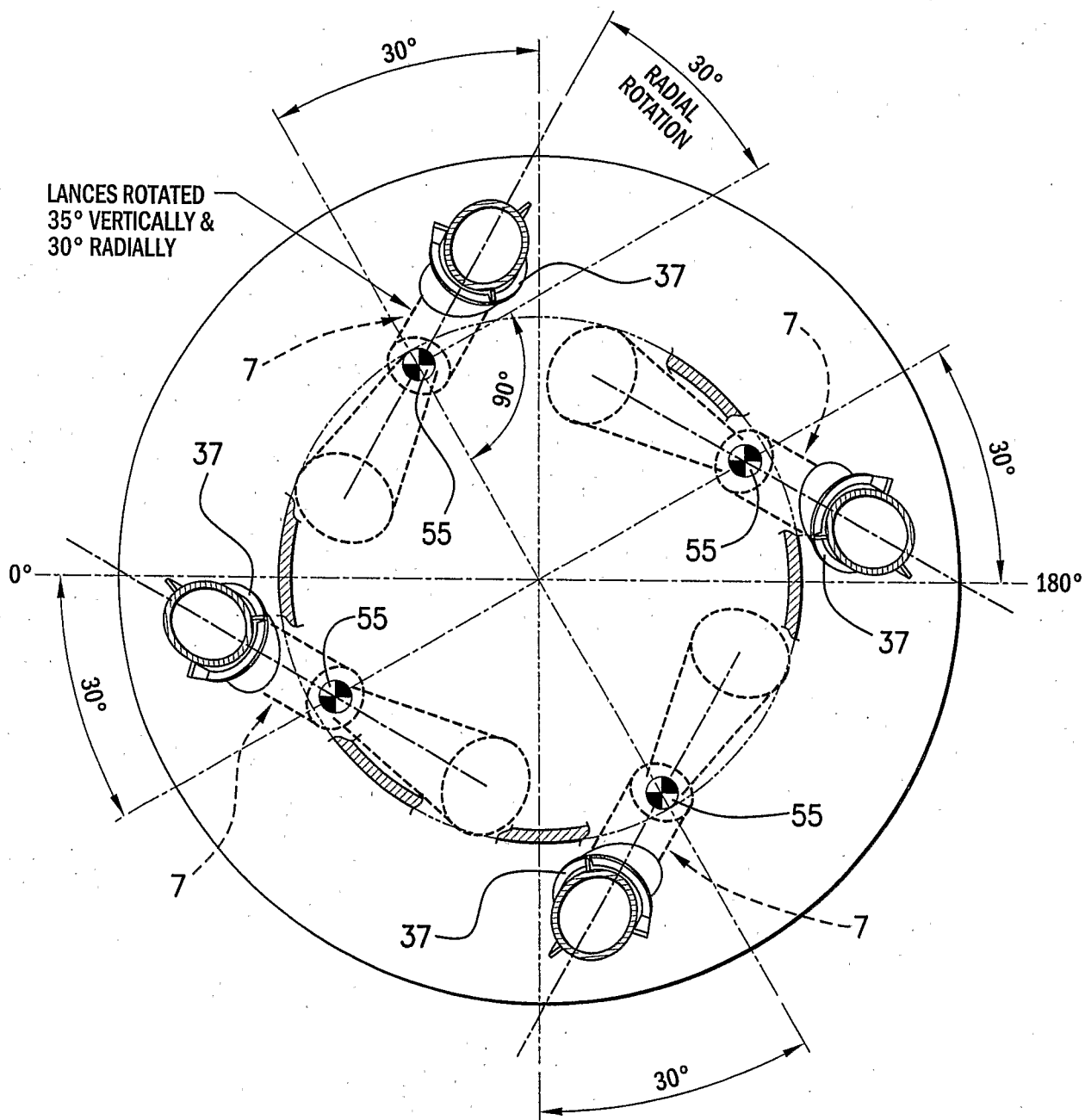
**FIG. 6**

FIG. 7



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**FIG. 8**

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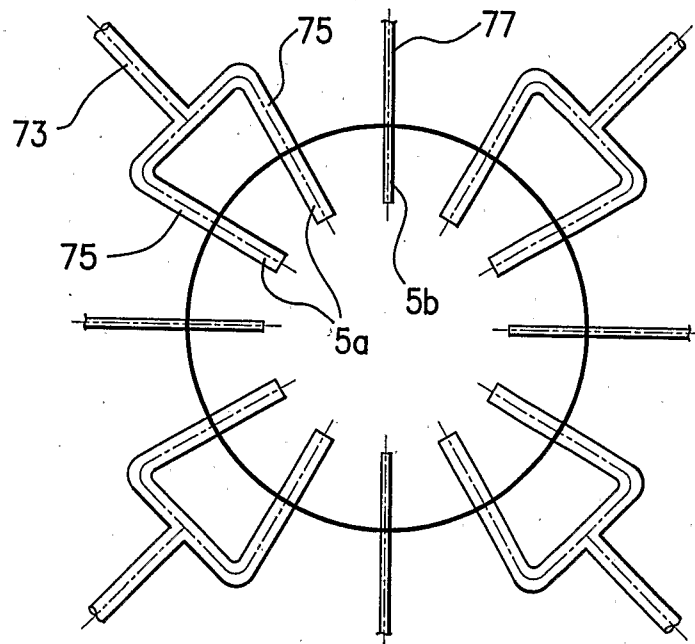


FIG. 9

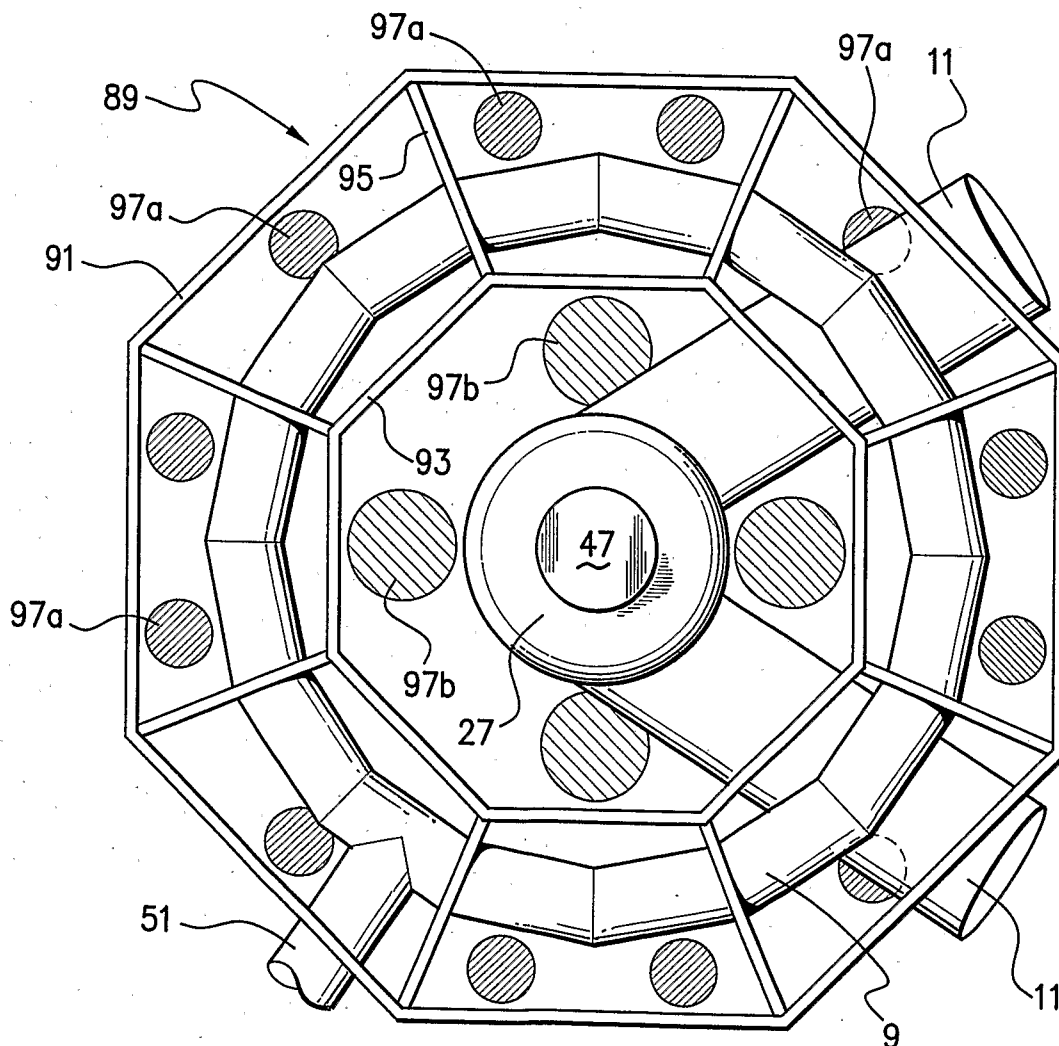


FIG 10

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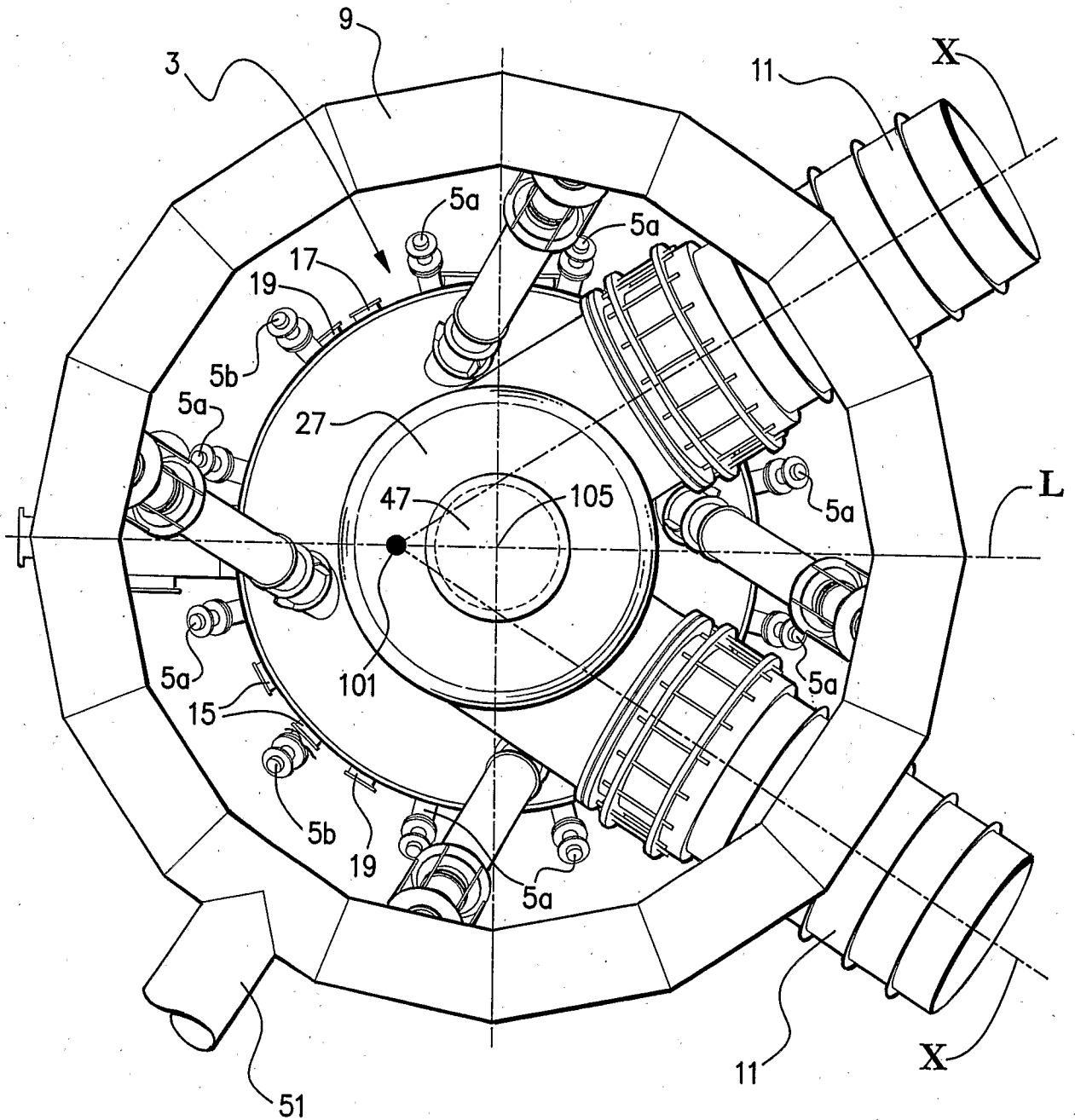
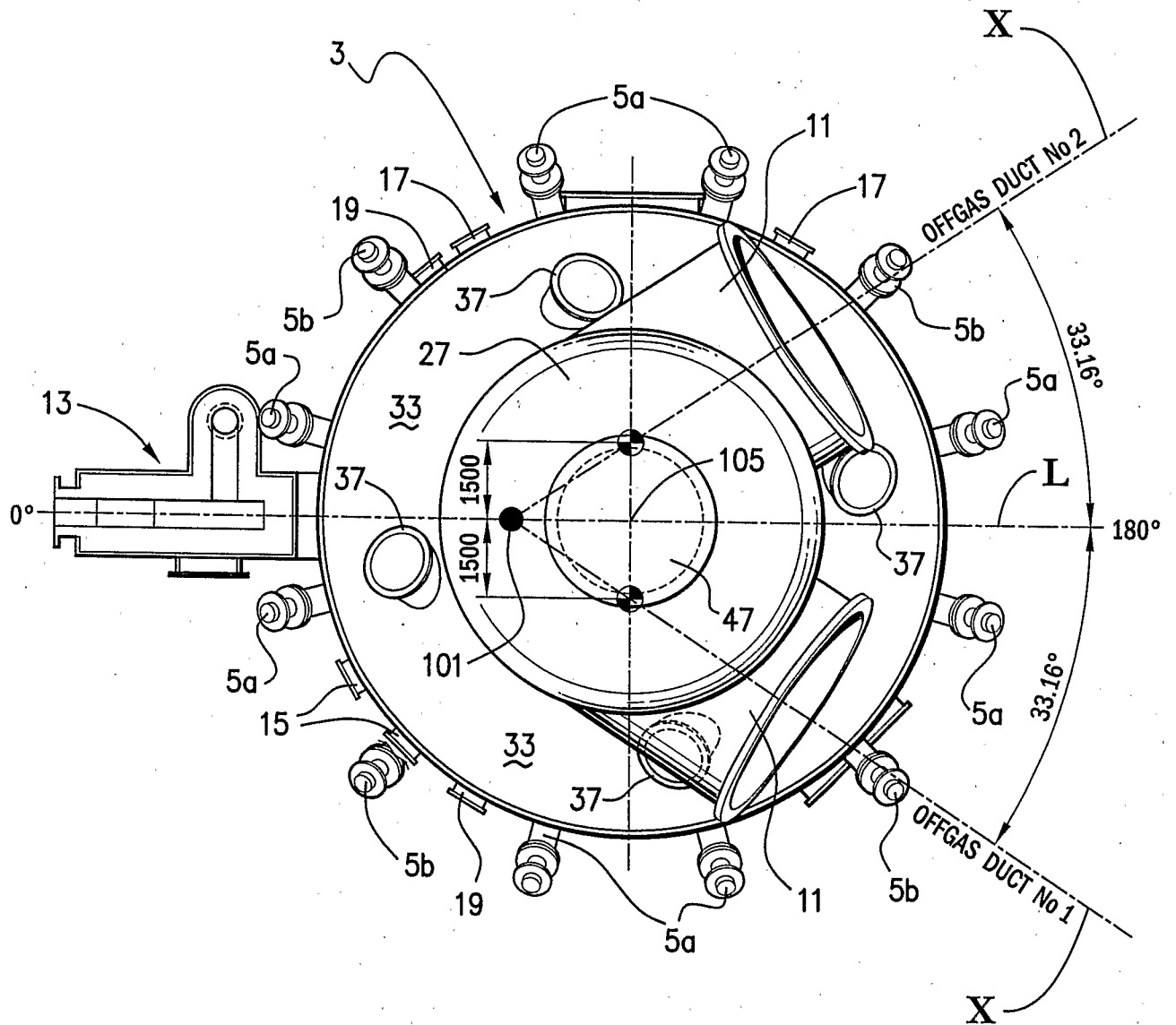
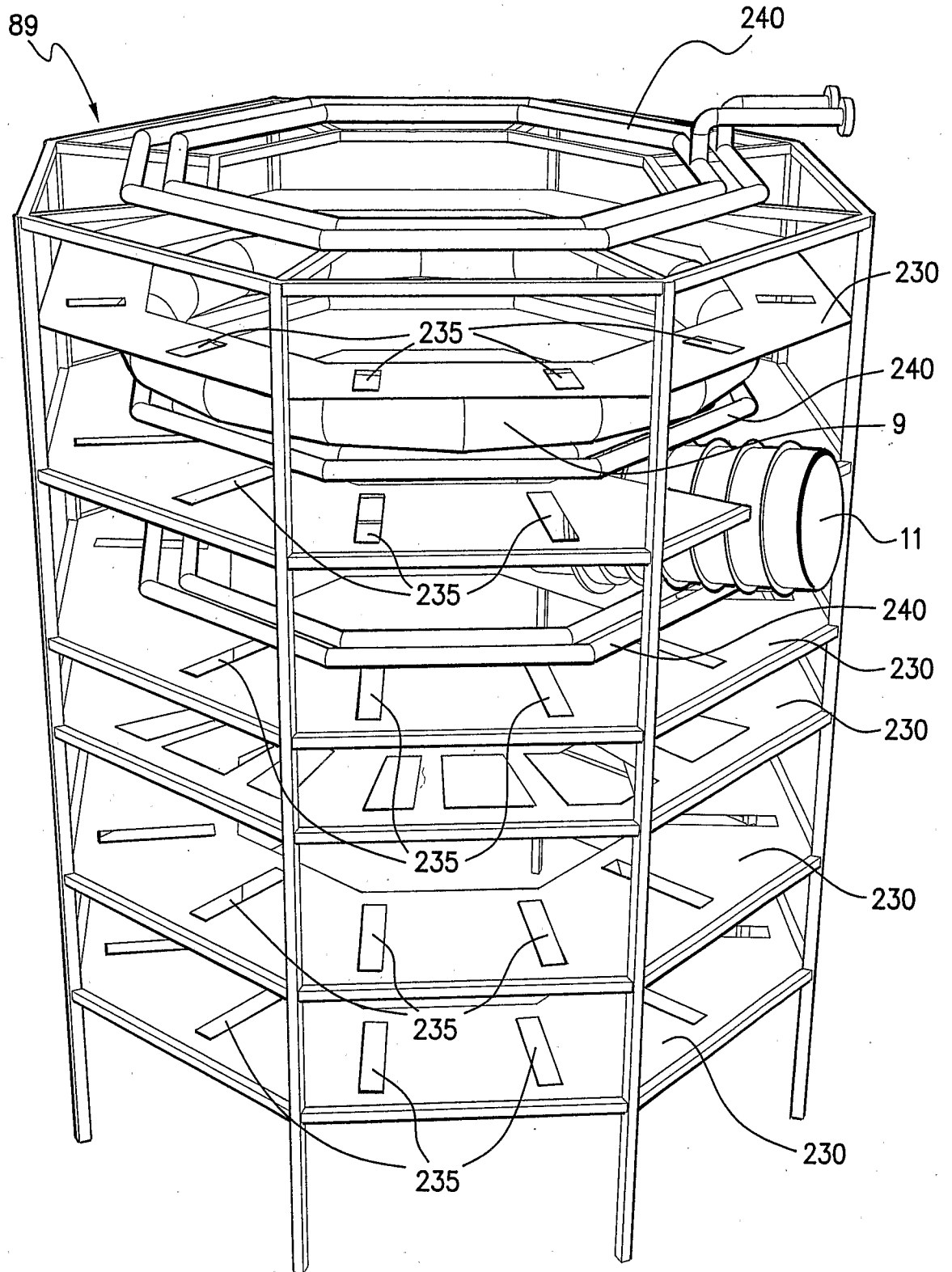


FIG. 11

**FIG. 12**

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**FIG. 14**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2007/000249

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

C21C 5/35 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC⁸: C21C 5/35, C21B 13/-, F27B 1/10

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Derwent WPI: IPC⁸ as above and (stir+ or circulat+ or centrif+ or swirl+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2004/090173 A1 (Technological Resources Pty. Ltd.) 21 October 2004 Whole Document	



Further documents are listed in the continuation of Box C



See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search
23 April 2007Date of mailing of the international search report
9 MAY 2007Name and mailing address of the ISA/AU
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/AU2007/000249

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report			Patent Family Member				
WO 2004090173	AU	2004228980	BR	PI0409281	CA	2521705	
	CN	1771339	EP	1625238	MX	PA05010733	
	RU	2005134213	US	7201868	US	2004262823	
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.							
END OF ANNEX							