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(54) **Vessel for enabling a uniform gravity driven flow of particulate bulk material therethrough, and direct reduction reactor incorporating same**

Gefäß zum Ermöglichen von gleichmassigem Schwerkraftabfluss von Schüttgut und
Direktreduktionsreaktor derselben enthaltend

Cuve permettant l'écoulement uniforme par gravité de matières en vrac et réacteur à réduction directe
la comportant

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Description

[0001] The invention relates to an improved configuration of bins, hoppers, silos, reactors, and more generally to any vessel for handling, processing, transporting or temporarily storing particulate bulk materials.

[0002] A particularly useful application of the invention is related to a Direct Reduction Reactor of particulate iron ores.

Background of the invention

[0003] It is common in many industries to use containers or vessels for handling, processing, transporting or temporarily storing particulate bulk materials. The geometrical configuration of such containers or vessels is of utmost importance in order to assure the desired type of flow of particles through said vessels. Depending on such factors and characteristics of the particles, as for example, the size and shape of the particles, the friction forces developed in the body of the bulk material as well as the friction forces between the particles and the wall of the container and the pressure exerted on said particles caused by the weight of the mass of particles, primarily the shape of the vessel but also its dimensions relative to the particles to be handled, determines whether the particles will flow freely by the action of gravity or will form bridges or domes which stop said flow or at least produce non-uniform flow thereof.

[0004] US patent 4,886,097 to Garza-Ondarza discloses a single segment container to handle particulate solids comprising a downwardly converging wall which wall is provided with an internal inverted step extending along a portion of the converging wall. The internal inverted step extends helically along at least a portion of the converging wall to provide a continuous increase in the cross-sectional area of the container to promote the flow of solids.

[0005] This patent provides an enlargement of the cross-sectional area of the container and in this way the solids compaction is minimized allowing configurations of the container with narrower outlet diameters. The measures proposed by this patent however, although effective in achieving its object, are difficult to incorporate in a cost-effective manner because the construction of the helical step along the conical portion of the container raises the costs incurred by the actual cutting and conformation of the metal sheet employed for constructing such container. This becomes more relevant when the spiral inverted step is to be incorporated in a large reactor which has to withstand high internal pressures.

[0006] US patent 6,055,781 describes a hopper that has been developed to reduce the tendency of particulate material to form bridges by providing a shape so that its walls slope downward more steeply with increasing height above the outlet. The disclosed hopper comprises several adjacent conical sections that are arranged along a common longitudinal axis. In the down-

ward direction, the conicity of the adjacent sections decreases.

[0007] US patent 3,797, 707 describes a bin for storage and flow of bulk solids having stepped hopper surfaces adapted to increase and render constant the rate of flow at the hopper outlet. The stepped surfaces have friction and slope angles adapted to satisfy the criteria for mass flow, and provide spaces for injecting fluid at one or more perimetric interfaces with the moving solids. This patent suggests an enlargement of the cross sectional area of the bin. To this end, it is propagated to arrange several conical segments adjacent one another and along a common longitudinal axis. The segments are dimensioned and arranged in the longitudinal direction so that they are joined by horizontal wall segments. The walls of this known container may still provide a support for the formation of domes by the particles. The injection of a fluid may not be possible to practice in many applications and entails additional operational costs.

[0008] US 3,921,351 discloses a segmented storage bin of circular or square cross-section for storing and dispensing particulate material comprising several bin segments; the cross-section of the bin is enlarged by the combination of intermediate wall segments providing an enlargement of the cross sectional area of the bin. The concept described in this patent however does not eliminate the formation of domes by the solid particles.

[0009] US 6,089,417 describes a chip bin comprising a discharge zone having a curvilinear roller shape in any freely chosen horizontal cross-section wherein the cross-section of the discharge zone decreases downwardly. In the cross-sectional view along the longitudinal axis of the known chip bin, some segments of the bin have a vertical wall on one side and an angled wall on the opposite side. The bin of this patent also has the disadvantage of a complicated and costly construction because of the shape of the segments as shown in the patent.

Summary of the invention

[0010] In view of this prior art, it is an object of the invention to provide a vessel or container that is inexpensive to manufacture and that promotes a uniform flow of particulate bulk materials therethrough. In particular, the stoppages caused by said materials hanging or dome bridging inside the converging zone of such container is to be minimized without resorting to moving parts.

[0011] This object is solved by a vessel having the features of claim 1. A further solution is provided by a direct reduction reactor having the features of claim 18 below. Further advantageous embodiments are provided in the dependent claims, respectively.

[0012] The present invention is based on the concept to provide an expansion of the cross sectional area of the inventive vessel which is asymmetrical at least in

one direction with respect to a horizontal plane. This feature of the invention produces a uniform gravity driven flow of particles and eliminates the possibility of formation of bridges or domes which interrupt the flow of particles.

[0013] This concept is reflected in the feature of claim 1 requiring the lower edge of the upper wall segment to extend outside a plane that is perpendicular to the longitudinal axis of the upper wall segment, and/or requiring the upper edge of the lower wall segment to extend outside a plane that is perpendicular to the longitudinal axis of the lower wall segment. Some wall segments of the present invention converge along their longitudinal axis. This convergence along a straight line facilitates easier manufacturing and assembly, but convergence of each converging wall segment along a curve is also contemplated. The angle of convergence is measured from the longitudinal axis to the wall of the wall segment, as seen in the direction of convergence.

[0014] Although it is preferred that the longitudinal axes of the wall segments of the inventive vessel coincide, it is also contemplated to arrange these axes parallel to and spaced from one another. Coinciding axes will improve the flow of particles through the inventive vessel, and spaced parallel axes allow for greater flexibility concerning the inventive vessel's requirement for space.

[0015] The direct reduction reactor in accordance with the present invention is particularly suitable for processing particles of iron oxides containing materials at high temperatures, so as to produce metallic iron in the solid state. In the inventive direct reduction reactor, the iron oxide particles can flow by gravity in a uniform plug flow pattern, and the range of lump ores and/or pellets expands, because the inventive direct reduction reactor minimizes the possibility of dome bridging in the discharge zone of the reactor.

[0016] The present invention provides a better solution to the tendency of solid particles to bridge within the container, by providing an enlargement of its cross-sectional area but with a better design and a more cost-effective facility for its construction.

[0017] Other features and advantages of the invention will be pointed out hereafter.

Brief description of the drawings

[0018]

- Figure 1 is a vertical side view of a vessel incorporating a preferred embodiment of the invention;
- Figure 2 is a plan view of the same embodiment of Figure 1;
- Figure 3 is a perspective external view of the embodiment of Figure 1;

Figure 4 shows a diagrammatic construction of the top segment of the vessel shown in Figure 1;

5 Figure 5 shows a diagrammatic construction of an intermediate segment of the vessel shown in Figure 1;

10 Figure 6 shows a diagrammatic construction of the bottom segment of the vessel shown in Figure 1;

15 Figure 7 is a diagrammatic side view of a direct reduction reactor embodying the present invention; and

20 Figure 8 is a side view of a storage bin embodying the present invention which may also comprise means for injecting a fluid to facilitate flow of the particulate material or react therewith.

Detailed description of a preferred embodiment

25 **[0019]** In the figures, a preferred embodiment of the present invention is depicted, and the inventive vessel is generally designated with reference numeral 10. Throughout the drawing figures, the same or corresponding elements are designated with identical reference numerals.

30 **[0020]** Although vessel 10 in Fig. 1 is depicted as having various conical segments 12, 14, 16, 18 and 20, it would be sufficient to embody the present invention, if the vessel 10 only comprised an upper wall segment 12, a lower wall segment 14, and an intermediate wall segment 34. In Fig. 1, various of these upper wall segments, lower wall segments and intermediate wall segments are depicted, the intermediate wall segments linking the respective upper and lower wall segments. In this manner, for example, conical wall segment 18 in Fig. 1 functions as an upper wall segment for the combination of wall segments 18, 40 and 20, and at the same time as a lower wall segment for the combination consisting of wall segments 16, 38 and 18. In this connection, it should be noted that, although the terminology "upper" and "lower" reflect the preferred orientation of the inventive vessel in use, such as it is depicted in Fig. 1, they mainly serve to identify relative orientations, and not to identify an absolute location or orientation of the inventive vessel.

50 **[0021]** Further with reference to Fig. 1, in the vertical cross-sectional view of a vessel 10 of a preferred embodiment of the invention, conical segments 12, 14, 16, 18 and 20 are depicted, all of which are generally centered with respect to the longitudinal, and in use of the vessel typically substantially vertical, axis 22 of vessel 10. In this preferred embodiment, the longitudinal axes of the various conical segments 12, 14, 16, 18 and 20

coincide, which is particularly evident from Fig. 2. It is, however, also within the scope of the invention to arrange the vertical axes of the conical segments 12, 14, 16, 18 and 20 so that they do not coincide, as long as they are arranged parallel to one another.

[0022] Conical segments 12 to 18 are generally shaped with an angle A with respect to their respective vertical axes. This angle A of the conical segments is selected in accordance with the flow characteristics of the particular solid bulk material to be handled by vessel 10, and in accordance with the optimization of the height of the vessel which results from steeper but more flow favorable values of angle A and from the necessity of having plug flow through the vessel or at an upper generally cylindrical section 26 of vessel 10.

[0023] Angle A will be selected by the skilled person in accordance with the application of vessel 10. For the preferred application, in direct reduction reactors, angle A is most preferably in the range from 11° to 18°. Although it is preferred to have segments 12 to 18 shaped with the same angle A, for some materials it may be desirable to decrease the angle A of each segment, with the smallest angle at the bottom of vessel 10. This decreasing conical angle A promotes the flow of particles to be more vertical where the cross-sectional area is smaller.

[0024] Segment 12 has a lower elliptical edge 24 resulting from truncating the cone 12 at an angle B. Angle B is in the range from 20° to 60° with respect to the horizontal, and more preferably between 35° to 45° with respect to the horizontal. In the preferred, substantially vertical orientation of vessel 10, these angles B translate into an angle in the range from 30° to 70°, and preferably 35° to 55° with respect to the longitudinal axis of wall segment 12. It is most preferred that angle B is 40°, so as to ensure optimum flow and to eliminate the possibility of formation of domes which could interrupt the flow of particles, in the preferred application of vessel 10. It is of course to be understood that the lower edge does not necessarily have to be elliptical, since the concept of the invention may be implied to vessels or containers having cross-sectional areas other than circular, for example rectangular.

[0025] Segments 14, 16 and 18 have similarly elliptical lower edges 26, 28, and 30, respectively. Each of the segments 12, 14, 16, 18 and 20 of vessel 10 cooperates with its adjacent segment or segments in order to provide an expansion of the cross sectional area of the flow channel of the preferably solid particles passing successively through segments 12 to 20. It is a distinctive feature of vessel 10 that this expansion of the cross sectional area is asymmetrical at least in one direction with respect to a horizontal plane. This minimizes the possibility of formation of bridges or domes by the gravity driven particles, because the supporting wall or supporting walls are asymmetric as regards the direction of gravity.

[0026] The preferably elliptical recess spaces en-

closed by the intermediate wall segments are oriented in the same direction, i.e. their longitudinal axis is oriented parallel to the longitudinal axes of conical segments 12, 14, 16, 18 and 20. The level of the highest point of each one of said intermediate wall segments is located at the same height or above the level of the lowest points of its associated upper wall segment, i.e. of the recess space above it, thus providing a continuous asymmetry in the walls of vessel 10; it should be noted that the invention also comprises embodiments where the space recesses are separated vertically by a distance longer or shorter than that depicted in the Figures, so that they effectively overlap or leave some zones without said cross-sectional area enlargements. The orientation of at least some or all of said recesses can also be different.

[0027] In Fig. 1, the lower edge portion 50 of the upper wall segment 12 is connected to the upper edge of intermediate wall element 34. As connection between the upper edge of the intermediate wall segment 34 and the upper wall segment 12 is preferably not with the lower edge 24 of upper wall segment 12, but with the lower edge portion 50, the mentioned overlap results, as depicted in Fig. 1. As it is understood in this document, the term lower edge portion includes the lower edge.

[0028] Intermediate wall segment 34 is with its lower edge attached to the upper edge of lower wall segment 14. The intermediate wall segment 34 is of generally circular cross-section and encloses a space 42 formed between the intermediate wall segment 34. This space 42 enlarges the effective cross sectional area of the vessel 10 and allows the particles to be handled to expand therein and to release some of the pressure acting on said downwardly flowing particles. The lower edge portion 50 of upper wall segment 12 may extend in this overlap over a certain distance L into vessel 10. The preferred value of this distance L will be selected in accordance with the size and shape of the particles to be handled, and also according to the heat transfer requirements which may be imposed by the temperatures inside vessel 10. For example, when the present invention is applied to reactors for the direct reduction of iron oxides where the particulate material may reach temperatures in the range of 500°C to 850°C, the length L may be in the range from 5 cm to 20 cm. In applications of the invention to reactors or bins handling particles at high temperatures, this overlap L may be dimensioned so that the heat transferred from the particles may be dissipated by conduction to the rest of the vessel wall thus advantageously dispensing with the need for additional cooling systems to cool said overlap.

[0029] Similar to intermediate wall segment 34, other intermediate wall segments 36, 38 and 40 are provided to define further expansions of the cross sectional area. These expansions are designated as 44, 46 and 48 (Fig. 1).

[0030] The upper and lower wall segments 12 to 20 may be constructed from conical shapes conformed-

and cut at the selected angle B, as shown in Figs. 4 to 6. As can be appreciated from these figures, and also from Fig. 3, there is a clear advantage in configuring upper and lower wall segments 12 to 20 as well as intermediate wall segments 34, 36, 38 and 40 in this manner. In particular, these segments may be manufactured with some tolerance to their dimensions, simply telescopically inserted into one another and subsequently be connected, for example by welding. This manufacturing is considerably more cost efficient than the prior art construction which proposed a continuous spirally shaped wall element.

[0031] In Fig. 4, the uppermost upper wall segment is depicted. It is of truncated cone shape with the base of the cone being depicted near the upper end of the Figure, and the plane of truncation depicted near the lower end of Fig. 4. The base of the cone shape of the uppermost upper wall segment 12 is perpendicular to the longitudinal axis 12', and the plane of truncation is inclined relative to the longitudinal axis 12'. In particular, the angle of inclination B is non-perpendicular to axis 12'.

[0032] The lower wall segment in the combination of wall segments 12, 34 and 14 (Fig. 3), namely wall segment 14, is depicted in more detail in Fig. 5. As is evident from Fig. 5, wall segment 14 is also of truncated cone shape, the base of the cone being depicted near the upper end of the Figure and in this case also inclined relative to the longitudinal axis 14' of segment 14. The angle of inclination relative to longitudinal axis 14' of segment 14 matches the angle of inclination of the plane of truncation of upper wall segment 12. Likewise, the angle of inclination B of the plane of truncation of wall segment 14 is inclined at the same angle B relative to its longitudinal axis 14'.

[0033] In Fig. 6, a further "lower" wall segment is depicted, in this case the lowermost wall segment of vessel 10 of Fig. 3. This lowermost wall segment 20 is also of truncated cone shape, the base being depicted near the upper end of the Figure, and the plane of truncation near the lower end of Fig. 6. The angle of inclination of the base of the cone shape of wall segment 20 is inclined at the same angle of inclination B relative to the longitudinal axis 20' of wall segment 20. In this manner, the vessel 10 depicted in Fig. 3 can more easily be manufactured and assembled. The lowermost wall segment can terminate in an outlet discharge 32 (Fig. 1).

[0034] Referring now to Fig. 7, reference numeral 52 generally designates a direct reduction reactor having an upper reduction zone 54 and a lower discharge zone 56.

Particulate iron oxides material in the form of lumps, pellets or mixtures thereof is fed to reactor 52 through feed pipes 58 and the material flows by gravity downwardly through reactor 52 at a regulated rate by conventional means (not shown for simplicity) and is discharged through outlet 60. The iron oxides are reduced to metallic iron by reaction with a reducing gas comprising hydrogen and carbon monoxide fed through feed inlet 62

and connected to distributing plenum 64 from which it is injected through nozzles 66 into the bed of particles, the gas flowing upwardly and counter-currently to the solid particles. The reacted gas is withdrawn through gas outlet 68 from which it is regenerated and recycled to reaction zone 54.

[0035] At the bottom portion of the conical discharge zone 56 vessel 70 is located which incorporates the features of the present invention as indicated by the same numerals designating the same elements shown in Fig. 1.

[0036] A typical direct reduction reactor has a diameter in its cylindrical part in the range of 4.5 to 6.5 meters, and its height is about 30 to 35 meters. The lowest portion where the invention is being incorporated (numeral 70) is about 7 meters tall, its wall converging from about 3 meters diameter to an outlet of about 1.0 meter diameter. The particles of reduced iron ore are comprised by lumps of irregular shape and pellets of generally spherical shape and mixtures of these materials. The particle size may vary from 3 mm to 30 mm and have a bulk density between 1.0 and 2.7 tons/cubic meter, usually from 1.4 to 2.0 tons/cubic meter. The friction angle between particles is typically in the range from 30 to 70 degrees and the friction angle between particles and the wall from about 20 to 35 degrees. Of course the values of friction angles vary in a wide range depending on many characteristics of the particles. The lowest segment of the reactor is usually made of carbon steel, but for some applications it may be made of high temperature resistant alloyed steel, (for example: inconel or stainless steel 304).

[0037] The tendency of the material in the reactor to form domes in vessel 70 wherein the internal diameter is smaller in comparison with the prior art is eliminated by the invention and the uniform flow of the solid particles throughout the reactor is improved thus rendering a more homogeneous quality of the product by the effect of the elliptical space recesses conformed and oriented at an angle B with respect to the reactor vertical axis, for example at 40°.

[0038] Fig. 8 shows a holding bin 72 incorporating the features of the invention and additionally comprising means 74, 76 and 78 for injecting a fluid, for example air or any suitable gas according to the material being handled, into the recess spaces 42, 46 and 48 enclosed by intermediate wall segments 34, 36, 38 and 40. This fluid injection may be a gas or liquid for aerating small sized particulate materials thus facilitating their flow through the bin, or may be a liquid or gas utilized for treatment or reaction with the particulate materials.

[0039] It is of course to be understood that many modifications may be made to the invention and that the invention may be carried out through several embodiments without departing from the scope thereof as it is set forth in the following claims; for example it will be evident that the vessel may have a shape other than conical, like square or rectangular, and that the internal

walls of the vessel may be lined with refractory or other material suitable for contacting the materials stored or processed in the vessel.

Claims

1. Vessel (10, 70) for enabling a uniform gravity driven flow of particulate bulk material therethrough, the vessel including at least

- an upper wall segment (12) having a longitudinal axis (Fig. 4: 12') and a wall converging along its longitudinal axis, the upper wall segment defining with an upper edge thereof a bulk material inlet, as well as
- a lower wall segment (14) having a longitudinal axis (Fig. 5: 14') and a wall converging along its longitudinal axis, the lower wall segment defining with a lower edge thereof a bulk material outlet, and
- a wall segment (34) intermediate the upper and the lower wall segments, the intermediate wall segment (34) being connected with an upper edge thereof to a lower edge portion (50) of the upper wall segment (12), and further being connected with a lower edge thereof to an upper edge of the lower wall segment (14)
- the lower edge of the upper wall segment (12) and/or the upper edge of the lower wall segment (14) extending outside a plane perpendicular to the longitudinal axis of the respective wall segment,
- the upper edge of the intermediate wall segment (34) defining a cross-sectional area larger than a cross sectional area defined by the lower edge (24) of the upper wall segment (12), and/or the lower edge of the intermediate wall segment (34) defining a cross-sectional area smaller than a cross sectional area defined by the upper edge of the lower wall segment (14).

2. Vessel as claimed in claim 1, wherein the intermediate wall segment (34) has a longitudinal axis and a wall parallel to its longitudinal axis.

3. Vessel as claimed in claims 1 or 2, wherein said intermediate wall segment (34) has a longitudinal axis and is connected such that the longitudinal axes of the upper wall segment, the lower wall segment and the intermediate wall segment are parallel to one another.

4. Vessel as claimed in claims 2 or 3, wherein the intermediate wall segment (34) is connected to the upper (12) and the lower (14) wall segments so that the longitudinal axes of the upper wall segment, the lower wall segment and the intermediate wall seg-

ment coincide and form a longitudinal axis (22) of the vessel.

5. Vessel as claimed in any of the preceding claims, wherein the converging wall of the upper wall segment (12) forms a converging angle (A) in the range from 8° to 45°, preferably 10° to 20° and more preferably 11° to 18° with respect to the longitudinal axis (14') thereof.

6. Vessel as claimed in any of the preceding claims, wherein the converging wall of the upper wall segment (12) defines a truncated cone shape, the upper edge of the upper wall segment defining the base of the cone and the lower edge (24) of the upper wall segment (12) defining the plane of truncation, and the base and/or the plane of truncation being inclined (B) relative to a plane perpendicular to the longitudinal axis (12') of the upper wall segment.

7. Vessel as claimed in claim 6, wherein the angle of inclination of the plane of truncation forms an angle (B) in the range from 30° to 70°, preferably 35° to 55° and more preferably 40° with respect to a plane perpendicular to the longitudinal axis of the upper wall segment.

8. Vessel as claimed in any of the preceding claims, wherein the converging wall of the lower wall segment (14) forms a converging angle (A) in the range from 8° to 45°, preferably 10° to 20° and more preferably 11° to 18° with respect to the longitudinal axis (14') thereof.

9. Vessel as claimed in any of the preceding claims, wherein the converging wall of the lower wall segment (14) defines a truncated cone shape, the upper edge of the lower wall segment defining the base of the cone and the lower edge of the lower wall segment defining the plane of truncation, and the base and/or the plane of truncation being inclined (B) relative to a plane perpendicular to the longitudinal axis (14') of the lower wall segment.

10. Vessel as claimed in claim 9, wherein the angle of inclination of the plane of truncation forms an angle (B) in the range from 30° to 70°, preferably 35° to 55° and more preferably 40° with respect to a plane perpendicular to the longitudinal axis (14') of the lower wall segment (14).

11. Vessel as claimed in any of the preceding claims, wherein the converging walls of the upper (12) and the lower (14) wall segments form converging angles (A) with respect to their respective longitudinal axis (12', 14'), the angles decreasing from the upper wall segment to the lower wall segment of said vessel.

12. Vessel as claimed in any of the preceding claims, wherein the intermediate wall segment (34) has a longitudinal axis and the wall of the intermediate wall segment (34) defines a cylinder, the upper edge of the intermediate wall segment defining an upper end plane inclined relative to the longitudinal axis of the intermediate wall segment, and/or the lower edge of the intermediate wall segment defining a lower end plane inclined relative to the longitudinal axis of the intermediate wall segment.
13. Vessel as claimed in claim 12, wherein the cylinder has an elliptical cross section.
14. Vessel as claimed in any of the preceding claims, including a plurality of upper wall segments (12, 14, 16, 18), the uppermost (12) of the upper wall segments defining with its upper edge the bulk material inlet of the vessel (10, 70), the vessel further including a plurality of lower wall segments (14, 16, 18, 20), the lowermost (20) of the lower wall segments defining with its lower edge the bulk material outlet of the vessel (10, 70).
15. Vessel as claimed in claim 14, further including a plurality of intermediate wall segments (34, 36, 38, 40).
16. Vessel as claimed in any of the preceding claims, wherein the upper and the lower wall segments generally have a circular or a rectangular cross section.
17. Vessel as claimed in any of the preceding claims for use as a holding bin (72) for particulate material and including means (74, 76, 78) to inject a fluid into the vessel, wherein said means is arranged to inject the fluid into at least one of the intermediate wall segments (34, 36, 38).
18. Direct reduction reactor (52) for processing particles containing iron oxides to produce particles containing metallic iron in the solid state, including a vessel (70) as claimed in any of the preceding claims.
19. Direct reduction reactor as claimed in claim 18, wherein the vessel (70) is located proximate to the discharge outlet (60) of the direct reduction reactor (52).
20. Direct reduction reactor as claimed in claim 18 or 19, wherein the vessel (70) has four intermediate wall segments (34, 36, 38, 40).

Patentansprüche

1. Behälter (10, 70), durch welchen ein partikelförmiges Schüttgut von der Schwerkraft angetrieben gleichmäßig hindurchströmen kann, welcher Behälter zumindest folgendes beinhaltet:
 - ein oberes Wandsegment (12) mit einer Längsachse (Fig. 4: 12') und einer entlang ihrer Längsachse konvergierenden Wand, das mit seiner oberen Kante einen Schüttguteinlass definiert, sowie
 - ein unteres Wandsegment (14) mit einer Längsachse (Fig. 5: 14') und einer entlang ihrer Längsachse konvergierenden Wand, das mit seiner unteren Kante einen Schüttgutausslass definiert, und
 - ein Wandsegment (34) zwischen dem oberen und dem unteren Wandsegment, das mit seiner oberen Kante mit einem unteren Kantenbereich (50) des oberen Wandsegments (12) und ferner mit seiner unteren Kante mit einer oberen Kante des unteren Wandsegments (14) verbunden ist,
 - wobei sich die untere Kante des oberen Wandsegments (12) und/oder die obere Kante des unteren Wandsegments (14) außerhalb einer rechtwinklig zur Längsachse des jeweiligen Wandsegments verlaufenden Ebene erstrecken, ,
 - und wobei die obere Kante des Wandzwischensegments (34) eine Querschnittsfläche definiert, die größer ist als eine von der unteren Kante (24) des oberen Wandsegments (12) definierte Querschnittsfläche, und/oder die untere Kante des Wandzwischensegments (34) eine Querschnittsfläche definiert, die kleiner ist als eine von der oberen Kante des Wandsegments (14) definierte Querschnittsfläche.
2. Behälter nach Anspruch 1, bei dem das Wandzwischensegment (34) eine Längsachse und eine Wand parallel zu seiner Längsachse aufweist.
3. Behälter nach Anspruch 1 oder 2, bei dem das Wandzwischensegment (34) eine Längsachse aufweist und so verbunden ist, dass die Längsachsen des oberen Wandsegments, des unteren Wandsegments und des Wandzwischensegments parallel zueinander sind.
4. Behälter nach Anspruch 2 oder 3, bei dem das Wandzwischensegment (34) mit den oberen (12) und unteren (14) Wandsegmenten so verbunden

ist, dass die Längsachsen des oberen Wandsegments, des unteren Wandsegments und des Wandzwischensegments zusammenfallen und eine Längsachse (22) des Behälters bilden.

5. Behälter nach einem der vorangehenden Ansprüche, bei dem die konvergierende Wand des oberen Wandsegments (12) einen konvergierenden Winkel (A) im Bereich von 8° bis 45° , vorzugsweise 10° bis 20° und noch stärker bevorzugt 11° bis 18° bezüglich seiner Längsachse (14') bildet. 5
6. Behälter nach einem der vorangehenden Ansprüche, bei dem die konvergierende Wand des oberen Wandsegments (12) eine Kegelstumpfgestalt definiert, wobei die obere Kante des oberen Wandsegments die Grundfläche des Kegels definiert und die untere Kante (24) des oberen Wandsegments (12) die Schnittebene definiert, und die Grundfläche und/oder die Schnittebene relativ zu einer Ebene rechtwinklig zur Längsachse (12') des oberen Wandsegments geneigt (B) sind/ist. 10
7. Behälter nach Anspruch 6, bei dem der Neigungswinkel der Schnittebene einen Winkel (B) im Bereich von 30° bis 70° , vorzugsweise 35° bis 55° und noch stärker bevorzugt 40° bezüglich einer Ebene rechtwinklig zur Längsachse des oberen Wandsegments bildet. 15
8. Behälter nach einem der vorangehenden Ansprüche, bei dem die konvergierende Wand des unteren Wandsegments (14) einen konvergierenden Winkel (A) im Bereich von 8° bis 45° , vorzugsweise 10° bis 20° und stärker bevorzugt 11° bis 18° bezüglich seiner Längsachse (14') bildet. 20
9. Behälter nach einem der vorangehenden Ansprüche, bei dem die konvergierende Wand des unteren Wandsegments (14) eine Kegelstumpfgestalt definiert, wobei die obere Kante des unteren Wandsegments die Grundfläche des Kegels definiert und die untere Kante des unteren Wandsegments die Schnittebene definiert, wobei die Grundfläche und/oder die Schnittebene relativ zu einer Ebene rechtwinklig zur Längsachse (14') des unteren Wandsegments geneigt (B) sind/ist. 25
10. Behälter nach Anspruch 9, bei dem der Neigungswinkel der Schnittebene einen Winkel (B) im Bereich von 30° bis 70° , vorzugsweise 35° bis 55° und noch stärker bevorzugt von 40° bezüglich einer Ebene rechtwinklig zur Längsachse (14') des unteren Wandsegments (14) bildet. 30
11. Behälter nach einem der vorangehenden Ansprüche, bei dem die konvergierenden Wände des oberen (12) und des unteren Wandsegments (14) kon-

vergierende Winkel (A) bezüglich ihrer jeweiligen Längsachse (12', 14') bilden, wobei diese Winkel von oberen Wandsegment hin zum unteren Wandsegment des Behälters abnehmen.

12. Behälter nach einem der vorangehenden Ansprüche, bei dem das Wandzwischensegment (34) eine Längsachse aufweist und die Wand des Wandzwischensegments (34) einen Zylinder definiert, wobei die obere Kante des Wandzwischensegments eine relativ zur Längsachse des Wandzwischensegments geneigte obere Endebene definiert, und/oder die untere Kante des Wandzwischensegments eine relativ zur Längsachse des Wandzwischensegments geneigte untere Endebene definiert. 35
13. Behälter nach Anspruch 12, bei dem der Zylinder einen elliptischen Querschnitt aufweist.
14. Behälter nach einem der vorangehenden Ansprüche, mit mehreren oberen Wandsegmenten (12, 14, 16, 18), wobei das oberste (12) der oberen Wandsegmente mit seiner oberen Kante den Schüttguteinlass des Behälters (10, 70) definiert, und weiter mit mehreren unteren Wandsegmenten (14, 16, 18, 20), wobei das unterste (20) der unteren Wandsegmente mit seiner unteren Kante den Schüttgutausslass des Behälters (10, 70) definiert. 40
15. Behälter nach Anspruch 14, weiter mit mehreren Wandzwischensegmenten (34, 36, 38, 40).
16. Behälter nach einem der vorangehenden Ansprüche, bei dem die oberen und unteren Wandsegmente im Wesentlichen einen kreisförmigen oder rechteckigen Querschnitt aufweisen.
17. Behälter nach einem der vorangehenden Ansprüche für die Verwendung als Haltesilo (72) für partikelförmiges Material, und mit Mitteln (74, 76, 78) zum Einspritzen eines Fluids in den Behälter, wobei diese Mittel so angeordnet sind, dass sie das Fluid in zumindest eines der Wandzwischensegmente (34, 36, 38) einspritzen. 45
18. Direktreduktionsreaktor (52) zum Bearbeiten von eisenoxidhaltigen Partikeln, um Partikel herzustellen, die metallisches Eisen beinhalten, und zwar im festen Zustand, mit einem Behälter (70) nach einem der vorangehenden Ansprüche. 50
19. Direktreduktionsreaktor nach Anspruch 18, bei dem der Behälter (70) sich neben dem Auslass (60) des Direktreduktionsreaktors (52) befindet. 55
20. Direktreduktionsreaktor nach Anspruch 18 oder 19, bei dem der Behälter (70) vier Wandzwischensegmente (34, 36, 38, 40) aufweist.

Revendications

1. Récipient (10, 70) pour y permettre le passage d'un flux régulier d'une matière particulaire en vrac, par un déplacement par gravité, le récipient comprenant au moins :
 - un segment de paroi supérieure (12) ayant un axe longitudinal (figure 4 : 12') et une paroi convergente le long de son axe longitudinal, le segment de paroi supérieure définissant, par un bord supérieur de celle-ci, une entrée de matière en vrac ; ainsi que
 - un segment de paroi inférieure (14) ayant un axe longitudinal (figure 5 : 14') et une paroi convergente le long de son axe longitudinal, le segment de paroi inférieure définissant, par un bord inférieur de celle-ci, une sortie de matière en vrac ; et
 - un segment de paroi (34), situé de façon intermédiaire entre les segments de paroi supérieure et inférieure, le segment de paroi intermédiaire (34) étant relié par un bord supérieur de celle-ci à une partie formant bord inférieur (50) du segment de paroi supérieure (12) et étant, en outre, relié par un bord inférieur de celle-ci à une partie formant bord supérieur du segment de paroi inférieure (14) ;
 - le bord inférieur du segment de paroi supérieure (12) et/ou le bord supérieur du segment de paroi inférieure (14) s'étendant à l'extérieur d'un plan perpendiculaire à l'axe longitudinal du segment de paroi respectif ;
 - le bord supérieur du segment de paroi intermédiaire (34) définissant une aire de section transversale qui est plus grande qu'une aire de section transversale, définie par le bord inférieur (24) du segment de paroi supérieure (12), et/ou le bord inférieur du segment de paroi intermédiaire (34) définissant une aire de section transversale qui est plus petite qu'une aire de section transversale, définie par le bord supérieur du segment de paroi inférieure (14).
2. Récipient selon la revendication 1, dans lequel le segment de paroi intermédiaire (34) a un axe longitudinal et une paroi, parallèle à son axe longitudinal.
3. Récipient selon la revendication 1 ou 2, dans lequel ledit segment de paroi intermédiaire (34) a un axe longitudinal et est relié de telle sorte que les axes longitudinaux du segment de paroi supérieure, du segment de paroi inférieure et du segment de paroi intermédiaire soient parallèles les uns aux autres
4. Récipient selon la revendication 2 ou 3, dans lequel le segment de paroi intermédiaire (34) est relié aux segments de paroi supérieure (12) et de paroi inférieure (14) de telle sorte que les axes longitudinaux du segment de paroi supérieure, du segment de paroi inférieure et du segment de paroi intermédiaire coïncident et forment un axe longitudinal (22) du récipient.
5. Récipient selon l'une quelconque des revendications précédentes, dans lequel la paroi convergente du segment de paroi supérieure (12) forme un angle convergent (A) compris dans la plage de 8° à 45°, de préférence de 10° à 20° et, de préférence encore, de 11° à 18° par rapport à l'axe longitudinal (14') de celui-ci.
6. Récipient selon l'une quelconque des revendications précédentes, dans lequel la paroi convergente du segment de paroi supérieure (12) définit une forme en cône tronqué, le bord supérieur du segment de paroi supérieure définissant la base du cône et le bord inférieur (24) du segment de paroi supérieure (12) définissant le plan de troncature, et la base et/ou le plan de troncature étant incliné(s) (B) par rapport à un plan perpendiculaire à l'axe longitudinal (12') du segment de paroi supérieure.
7. Récipient selon la revendication 6, dans lequel l'angle d'inclinaison du plan de troncature forme un angle (B) compris dans la plage de 30° à 70°, de préférence de 35° à 55° et, de préférence encore, un angle de 40° par rapport à un plan perpendiculaire à l'axe longitudinal du segment de paroi supérieure.
8. Récipient selon l'une quelconque des revendications précédentes, dans lequel la paroi convergente du segment de paroi inférieure (14) forme un angle convergent (A) compris dans la plage de 8° à 45°, de préférence de 10° à 20° et, de préférence encore, de 11° à 18° par rapport à l'axe longitudinal (14') de celui-ci.
9. Récipient selon l'une quelconque des revendications précédentes, dans lequel la paroi convergente du segment de paroi inférieure (14) définit une forme en cône tronqué, le bord supérieur du segment de paroi inférieure définissant la base du cône et le bord inférieur du segment de paroi inférieure définissant le plan de troncature, et la base et/ou le plan de troncature étant incliné(s) (B) par rapport à un plan perpendiculaire à l'axe longitudinal (14') du segment de paroi inférieure.
10. Récipient selon la revendication 9, dans lequel l'angle d'inclinaison du plan de troncature forme un angle (B) compris dans la plage de 30° à 70°, de préférence de 35° à 55° et, de préférence encore, un angle de 40° par rapport à un plan perpendiculaire à l'axe longitudinal (14') du segment de paroi inférieure.

rieure (14).

11. Récipient selon l'une quelconque des revendications précédentes, dans lequel les parois convergentes des segments de paroi supérieure (12) et de paroi inférieure (14) forment des angles convergents (A) par rapport à leurs axes longitudinaux respectifs (12', 14'), les angles allant en diminuant depuis le segment de paroi supérieure jusqu'au segment de paroi inférieure dudit récipient. 5
12. Récipient selon l'une quelconque des revendications précédentes, dans lequel le segment de paroi intermédiaire (34) a un axe longitudinal, et la paroi du segment de paroi intermédiaire (34) définit un cylindre, le bord supérieur du segment de paroi intermédiaire définissant un plan d'extrémité supérieure, qui est incliné par rapport à l'axe longitudinal du segment de paroi intermédiaire, et/ou le bord inférieur du segment de paroi intermédiaire définissant un plan d'extrémité inférieure, qui est incliné par rapport à l'axe longitudinal du segment de paroi intermédiaire. 10 15 20
13. Récipient selon la revendication 12, dans lequel le cylindre a une section transversale elliptique. 25
14. Récipient selon l'une quelconque des revendications précédentes, comprenant une pluralité de segments de paroi supérieure (12, 14, 16, 18), le plus haut (12) des segments de paroi supérieure définissant, par son bord supérieur, l'entrée de matière en vrac du récipient (10, 70), le récipient comprenant en outre une pluralité de segments de paroi inférieure (14, 16, 18, 20), le segment le plus bas (20) des segments de paroi inférieure définissant, par son bord inférieur, la sortie de matière en vrac du récipient (10, 70). 30 35
15. Récipient selon la revendication 14, comprenant en outre une pluralité de segments de paroi intermédiaire (34, 36, 38, 40). 40
16. Récipient selon l'une quelconque des revendications précédentes, dans lequel les segments de paroi supérieure et de paroi inférieure ont globalement une section transversale circulaire ou rectangulaire. 45
17. Récipient selon l'une quelconque des revendications précédentes, pour une utilisation en tant que trémie (72) pour une matière particulaire et comprenant des moyens (74, 76, 78) pour injecter un fluide dans le récipient, dans lequel lesdits moyens sont disposés pour injecter le fluide dans au moins l'un des segments de paroi intermédiaire (34, 36, 38). 50 55
18. Réacteur de réduction directe (52) pour traiter des

particules contenant des oxydes de fer, afin de produire des particules contenant du fer métallique à l'état solide, et comprenant un récipient (70) selon l'une quelconque des revendications précédentes.

19. Réacteur de réduction directe selon la revendication 18, dans lequel le récipient (70) est situé à proximité immédiate de l'orifice d'évacuation (60) du réacteur de réduction directe (52).
20. Réacteur de réduction directe selon la revendication 18 ou 19, dans lequel le récipient (70) comporte quatre segments de paroi intermédiaire (34, 36, 38, 40).

Figure 2

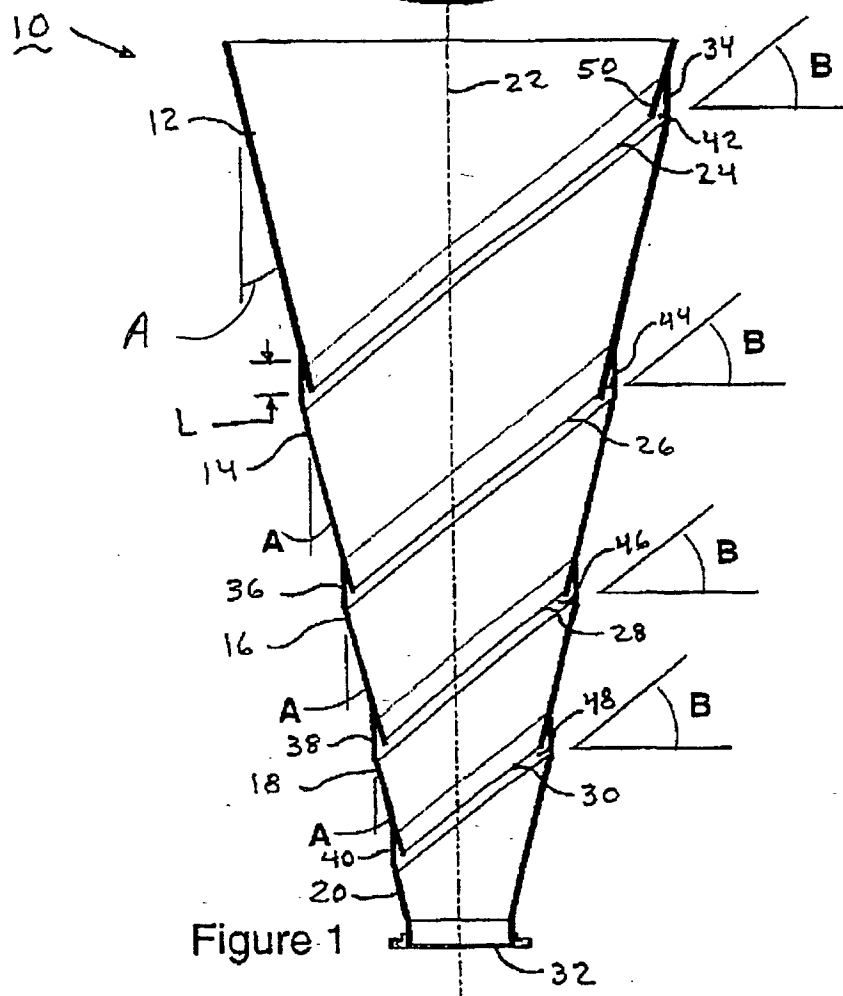
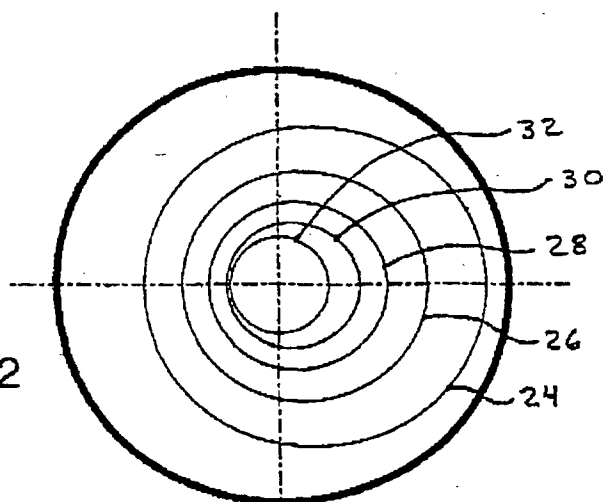


Figure 1

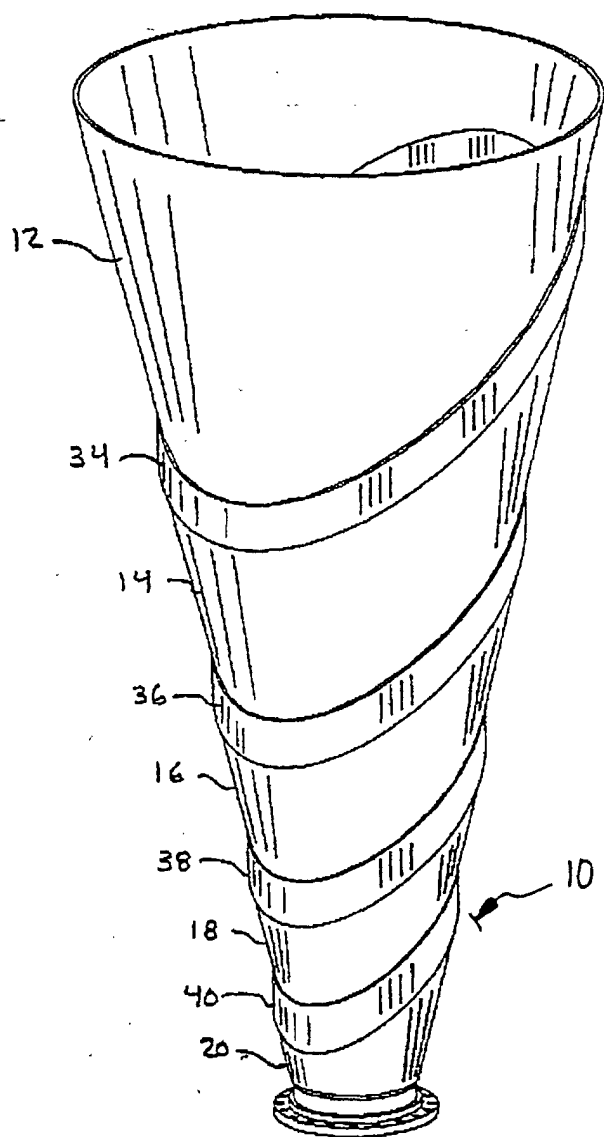


Figure 3

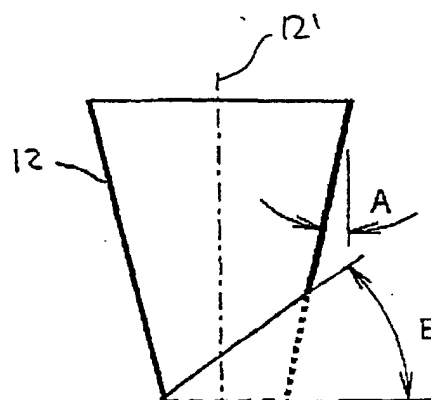


Figure 4

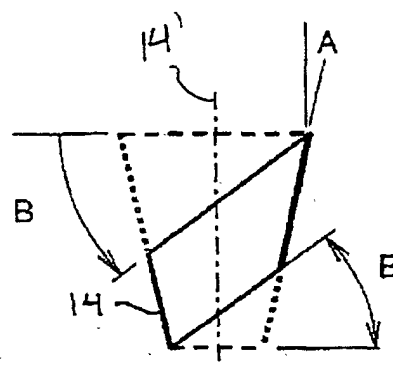


Figure 5

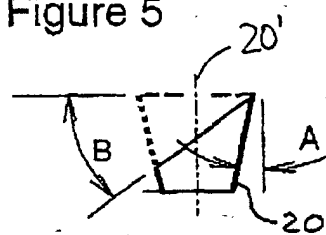


Figure 6

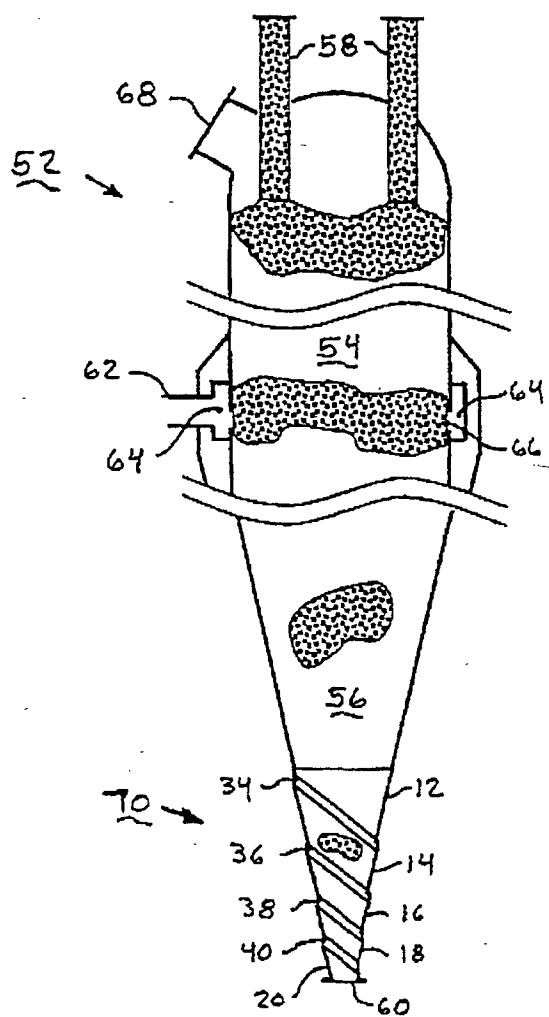


Figure 7

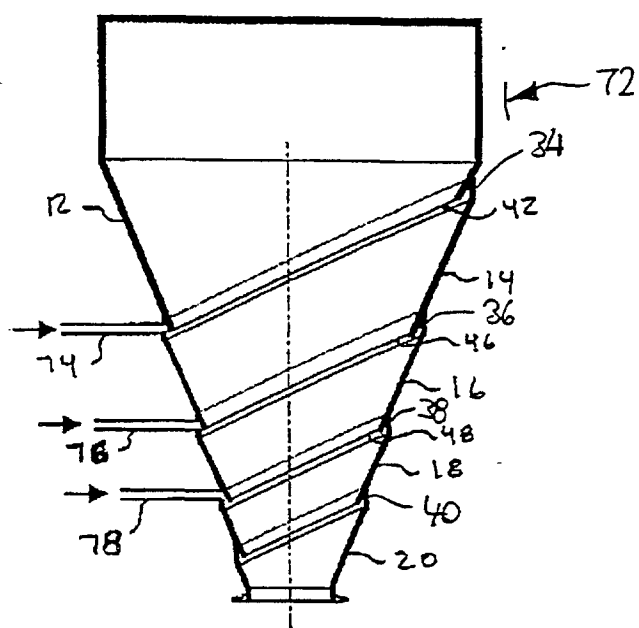


Figure 8