(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 550 242 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
09.10.2019 Bulletin 2019/41

(51) Int Cl.:
F26B 3/08 *(2006.01)* ***F26B 17/10*** *(2006.01)*

(21) Application number: **19171293.4**

(22) Date of filing: **14.10.2015**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Validation States:
MA

(30) Priority: **15.10.2014 EP 14189037**

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
18154880.1 / 3 351 884
15189711.3 / 3 009 777

(71) Applicant: **ASJ-IPR ApS**
2800 Kgs. Lyngby (DK)

(72) Inventor: **SLOTH JENSEN, Arne**
2800 Kgs. Lyngby (DK)

(74) Representative: **Budde Schou A/S**
Hausergade 3
1128 Copenhagen K (DK)

Remarks:
This application was filed on 26.04.2019 as a divisional application to the application mentioned under INID code 62.

(54) AN APPARATUS FOR DRYING BULK PARTICULATE MATERIAL AND A METHOD OF DRYING BULK PARTICULATE MATERIAL

(57) An apparatus for drying bulk particulate material, the apparatus comprises 1) a vessel capable of maintaining superheated steam at a pressure equal to or larger than the ambient pressure surrounding the vessel. The vessel defines a lower cylindrical part which defines a first cross-sectional area which is perpendicular to the length of the lower cylindrical part and an upper cylindrical part which defines a second cross-sectional area which is perpendicular to the length of the upper cylindrical part; 2) an inner cylindrical part centrally located within the upper cylindrical part and the lower cylindrical part of the vessel to establish a first fluid path from the upper cylindrical part to the lower cylindrical part within the inner cylindrical part and a second fluid path from the lower cylindrical part to the upper cylindrical part outside the inner cylindrical part; 3) a first number of partitioning walls which extend radially within the lower cylindrical part between the lower cylindrical part and the inner cylindrical part and which defines in the lower cylindrical part an inlet chamber, an outlet chamber and a second number of intermediate chambers located between the inlet chamber and the outlet chamber in a circumferential direction, the inlet chamber comprises an inlet in order to receive a moist bulk particulate materials, the outlet chamber comprises an outlet for ejecting a dry bulk particulate materials, the inlet chamber and the intermediate chambers each defines a steam permeable bottom, the outlet chamber defines a non-steam permeable bottom; 4) a heat exchanger located within the inner cylindrical part for heating the superheated steam; 5) an impeller to generate a flow of superheated steam along the first fluid path from the upper cylindrical part through the heat exchanger within the inner cylindrical part to the lower cylindrical part via the steam permeable bottom, and along the second fluid path from the lower cylindrical part to the upper cylindrical part outside the inner cylindrical part; and 6) the steam permeable bottom of the inlet chamber which is adapted to receive between 20% and 50% of the flow of superheated steam from the impeller.

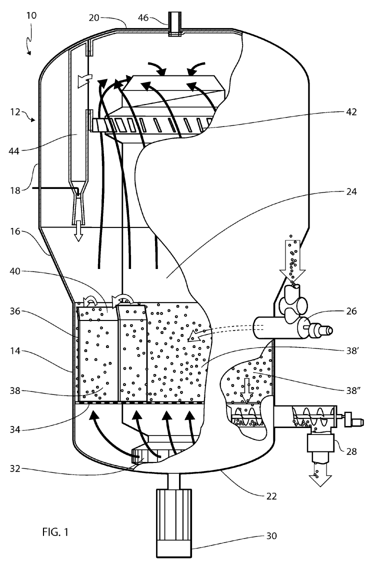

FIG. 1

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Description

[0001] The present invention relates to an apparatus for drying bulk particulate material and a method of drying bulk particulate material, the bulk particulate material in particular being sugar beet pulp.

Background of the invention

[0002] Drying of moist bulk particulate material by contacting the particulate material with superheated steam under non-oxidizing conditions to evaporate liquid contained in the material has been known since the early 1980s. Some documents showing related art include: AT 345769 B, EP 0 268 819, EP 0 955 511 A2, EP 1 044 044 A1, EP 1 070 223 A1, EP 1 956 326 B1, EP 2 457 649 A1, US 4 602 438, US 4 813 155, US 5 357 686 A, US 6 154 979 A, US 6 266 895, US 6 438 863 B1, US 6 966 466 B2, US 7 578 073 B2, WO 2010/139331 A2.

[0003] An early disclosures of the above-mentioned steam drying technologies include EP 0 058 651 A1 which relates to a method of preparing cattle feed from various agricultural products, such as sugar beet pulp, molasses, citrus fruit pulp and peel and various fermentation products.

[0004] Another disclosure is EP 0 153 704 A2 which teaches a process of removing liquid from a particulate solid material in which the material is passed through a row of interconnected cells and superheated steam is introduced into said cells at their lower ends so as to impart a whirling movement during which dried panicles are lifted out of the cells and into a common transfer zone and into a discharge cell with no steam supply.

[0005] The prior art document WO 92/01200 discloses an apparatus for drying a moist particulate material having a non-uniform particle size with superheated steam. The apparatus comprises a cylindrical vessel comprising a number of parallel, substantially vertical drying chambers located in ring form. The preferred embodiment includes 15 drying chambers connected in series, and a discharge chamber located between the first and the last drying chamber.

[0006] At the first drying chamber after the inlet, the particulate material will have a high liquid content whereas the particulate material at the last drying chamber will have a low liquid content. The drying chambers are adapted to induce a whirling movement of the flow of superheated steam in order to improve the contact between the steam and the particulate material and to cause the particulate material to remain a short and uniform time period within each of the drying chambers. The drying chambers, however, all have a substantially uniform size and shape and receive about the same amount of superheated steam although it is evident that the particulate material will behave differently when it is moist and when it is dry. In particular, the moist particles tend to be heavier than the dry particles and thus cause a larger flow resistance.

[0007] It has been noted by the applicant that the moist particulate material, and in particular the large and heavy particles, tend to accumulate in first drying chamber. Particulate material remaining an extended time period in the first drying chamber may potentially clog the first drying chamber and reduce the intensity of the whirling movement of the flow of superheated steam. Previous technologies suggest the inclusion of means for increasing the retention time of the particulate material in some of the drying chambers and means for reducing the retention time of the particulate material in some of the other drying chambers. However, such means may add to the flow resistance and risk reducing the whirling movement of the flow of superheated steam which is necessary for achieving an effective drying of the particulate material. The whirling movement allows the particulate material to distribute more evenly within the chamber which will result in a more effective drying than particulate material which clogs up and forms large chunks of material.

[0008] It is thus an object of according to the present invention to provide technologies for avoiding accumulation of material within the first drying chamber.

Summary of the invention

[0009] The above object and further objects which are evident from the below detailed description are according to a first aspect of the present invention achieved by an apparatus for drying bulk particulate materials, the apparatus comprising:

a vessel capable of maintaining superheated steam at a pressure equal to or larger than the ambient pressure surrounding the vessel, the vessel defining a lower cylindrical part defining a first cross-sectional area being perpendicular to the length of the lower cylindrical part and an upper cylindrical part defining a second cross-sectional area being perpendicular to the length of the upper cylindrical part,

an inner cylindrical part centrally located within the upper cylindrical part and the lower cylindrical part of the vessel for establishing a first fluid path from the upper cylindrical part to the lower cylindrical part within the inner cylindrical part and a second fluid path from the lower cylindrical part to the upper cylindrical part outside the inner cylindrical part,

a first number of partitioning walls extending radially within the lower cylindrical part between the lower cylindrical part and the inner cylindrical part and defining in the lower cylindrical part an inlet chamber, an outlet chamber and a second number of intermediate chambers located between the inlet chamber and the outlet chamber in a circumferential direction, the inlet chamber comprising a inlet for receiving a moist bulk particulate material, the outlet chamber comprising an outlet for ejecting a dry bulk particulate material, the inlet chamber and the intermediate chambers each defining a steam permeable bottom, the outlet chamber defining a non-steam permeable bottom,

a heat exchanger located within the inner cylindrical part for heating the superheated steam,

an impeller for generating a flow of superheated steam along the first fluid path from the upper cylindrical part through the heat exchanger within the inner cylindrical part to the lower cylindrical part via the steam permeable bottom, and along the second fluid path from the lower cylindrical part to the upper cylindrical part outside the inner cylindrical part, and the steam permeable bottom of the inlet chamber being adapted to receive between 20% and 50% of the flow of superheated steam from the impeller, said inlet chamber being larger than any of the intermediate chambers and hereby occupy a larger circular sector of the ring-shaped space between the lower cylindrical part and the inner cylindrical part.

[0010] The vessel is typically made of metal capable of withstanding temperatures of superheated steam exceeding 100°C and pressures exceeding the ambient atmospheric pressure. Typical pressures range from ambient atmospheric pressures to a pressure of up to 3 bar. The vessel comprises a lower cylindrical part and an upper cylindrical part which form part of the outer enclosure of the vessel. The vessel further comprises a top part and a bottom part in order to form an essentially enclosed vessel.

[0011] The first flow path inside the inner cylindrical part and the second flow path between the outer enclosure of the vessel and the inner cylindrical part define the recirculation of the superheated steam. The flow of superheated steam is established by the impeller which is located in the lower cylindrical part below the steam permeable bottom and/or between the inner cylindrical part and the steam permeable bottom of the lower cylindrical part in order to establish a high pressure below the steam permeable bottom, which in turn establishes a fluid bed and the re-circulating flow of superheated steam. The inner cylindrical part includes the heat exchanger which maintains the re-circulating steam in a superheated state for avoiding any condensation to occur within the vessel.

[0012] The drying is taking place by superheated steam contacting the moist particulate material and transferring some of its heat to the moist particles. The liquid content of the moist particulate material will vaporize and the vapor becomes part of the superheated steam. The heat energy required for the vaporization and thereby removed from the superheated steam is replenished at the heat exchanger in order to avoid condensation of the superheated steam into liquid within the vessel. Any surplus steam may be released via an overpressure valve at the top part of the vessel. The vessel also includes means for inducing a circumferential flow component in order to cause the particulate material to move slowly in a circumferential direction from the inlet to the outlet.

[0013] The partitioning walls serve to delimit the lower cylindrical part into several chambers. The first chamber is the inlet chamber which is connected to a closed off screw conveyor or the like for injecting the moist particulate material into the inlet chamber. The outlet chamber also comprises a closed off screw conveyor or the like for discharging the dry particulate material. The intermediate chambers are located between inlet chamber and the outlet chamber. The partitioning walls include openings for allowing particulate material to be transported from the inlet chamber to the outlet chamber via the intermediate chambers. The inlet chamber and the intermediate chambers receive superheated steam from a steam permeable bottom and thus constitute drying chambers.

[0014] Within the drying chambers a whirling fluid bed and a whirling flow is established which maintains most of the particulate material in the lower cylindrical part and increases the contact between the superheated steam and the particulate material. The outlet chamber does not have a steam permeable bottom to allow the particulate material to settle before being discharged. The number of chambers determines the retention time of the particulate material within the vessel and the mixing behaviour of the particulate material within each of the chambers. A small number of chambers reduces the retention time of the particulate material while allowing the particulate material to distribute more uniformly within the chamber, and vice versa.

[0015] The particulate material arriving at the first drying chamber, i.e. the inlet chamber, is moist and contains a large portion of liquid and thus tends to be heavy and clogging up the chamber. These particles generate a large drag and the flow velocity of the superheated steam is reduced due to the increased flow resistance. This leads to less lift in the fluid bed, less whirling motion of the flow and less distribution of the particulate material which results in the accumulation of moist particulate material in some parts of the inlet chamber. The particulate material arriving at the last drying chamber before the outlet chamber in which the now dried particulate material is ejected, is substantially dry and light and well distributed within the chamber since nothing is preventing the formation of an effective whirling flow of superheated steam. This may lead to increased lift in the fluid bed and a large amount of particulate material flowing into the upper cylindrical part of the vessel

[0016] Thus, in order to ensure the formation of a well established whirling flow of superheated steam within the inlet chamber, the heavy and liquid particulate material contained in the first chamber should receive a larger portion of the superheated steam received from the inner cylindrical part via the impeller. By allowing the inlet chamber to receive between 20% and 50% of the superheated steam, a sufficient flow of superheated steam may form which will generate sufficient lift to be capable of overcoming the drag of the moist particulate material. Thus, a uniform distribution of the particulate material may be achieved in all of the drying chambers.

[0017] According to a first embodiment of the first aspect, the inlet chamber is adapted to receive between 22% and 45% of the superheated steam received from the inner cylindrical part, preferably between 25% and 40% of the superheated steam received from the inner cylindrical part, more preferably between 30% and 35% of the superheated steam received from the inner cylindrical part, such as 33% of the superheated steam received from the inner cylindrical part, alternatively, the inlet chamber being adapted to receive between 20% and 22% of the superheated steam received from the inner cylindrical part, and/or between 22% and 25% of the superheated steam received from the inner cylindrical part, and/or between 25% and 30% of the superheated steam received from the inner cylindrical part, and/or between 30% and 35% of the superheated steam received from the inner cylindrical part, and/or between 35% and 40% of the superheated steam received from the inner cylindrical part, and/or between 40% and 45% of the superheated steam received from the inner cylindrical part, and/or between 45% and 50% of the superheated steam received from the inner cylindrical part.

[0018] Intense research performed by the applicant has indicated that for many drying applications of moist particulate material, such as beet pulp drying, the optimal drying capability is achieved by using the above percentages.

[0019] According to a further embodiment of the first aspect, the inlet chamber and the intermediate chambers each define a flow area being parallel with the first cross-sectional area, the flow area of the inlet chamber being greater than the flow area of any of the intermediate chambers.

[0020] One mode of realizing the above is to make the inlet chamber larger than any of the intermediate chambers. In this way a larger portion of the superheated steam will enter the inlet chamber. The cross-sectional area of the inlet chamber may thus constitute at least 20% of the cross-sectional area of all of the chambers, preferably any of the previously mentioned percentages.

[0021] According to a further embodiment of the first aspect, the partitioning walls define a first partitioning wall and a second partitioning wall both delimiting the inlet chamber in the circumferential direction, the first partitioning wall and a second partitioning wall defining an angle them between of between 50° and 180°, preferably between 70° and 160, more preferably between 90° and 140°, such as 120°.

[0022] By allowing the inlet chamber to occupy a larger circular sector of the ring-shaped space between the lower cylindrical part and the inner cylindrical part, the inlet chamber will receive a larger portion of the superheated steam from the impeller, provided the superheated steam is uniformly distributed over the ring-shaped space.

[0023] According to a further embodiment of the first aspect, the steam permeable bottom of the inlet chamber defines a steam permeability of between 20% and 45% of the steam permeability of the total steam permeability of all of the steam permeable bottoms, preferably between 25% and 40%, more preferably between 30% and 35%, such as 33% .

[0024] Alternatively, instead of making the inlet chamber larger, all chambers may have the same size and the permeability of the steam permeable bottom may be higher for the inlet chamber compared to the intermediate chambers. In this way, a larger portion of the superheated steam will enter the inlet chamber.

[0025] According to a further embodiment of the first aspect, the steam permeable bottoms of the inlet chamber and the intermediate chambers define perforations.

[0026] The perforations will be located between the impeller and the fluid bed. The size of each individual perforation should be made such that no particulate material may slip through into the impeller.

[0027] According to a further embodiment of the first aspect, the perforations of the steam permeable bottoms of the inlet chamber define an area being 20% to 45% of the total area of all of the perforations of all of the steam permeable bottoms, preferably between 25% and 40%, more preferably between 30% and 35%, such as 33%.

[0028] Intense research performed by the applicant has indicated that for many drying applications of moist particulate material, such as beet pulp drying, the optimal drying capability is achieved by using the above percentages.

[0029] According to a further embodiment of the first aspect, the vessel comprises an intermediate conical part interconnecting the lower cylindrical part and the upper cylindrical part so that the second cross-sectional area is larger than the first cross-sectional area.

[0030] In order to prevent the accumulation of particulate material in the upper cylindrical part of the vessel, the lower cylindrical part and the upper cylindrical part may be interconnected by the conical part in which the flow velocity will decrease due to the increasing flow area, as described by the Bernoulli principle. In this way, the lift will decrease in the upper cylindrical part and most of the particulate material in the conical part will not reach the upper cylindrical part and any particulate material appearing in the upper cylindrical part will fall back into the lower cylindrical part.

[0031] According to a further embodiment of the first aspect, the second cross-sectional is substantially equal to the first cross-sectional area.

[0032] Alternatively, there is no conical part and the first and second cylindrical parts have the same diameter.

[0033] According to a further embodiment of the first aspect, all of the steam originates from the moist bulk particulate material.

[0034] Preferably, no superheated steam must be separately added to the vessel as the superheated steam may be generated from the liquid which is vaporized from the moist particulate material. The surplus superheated steam may, as described above, be let out via an overpressure valve or outlet, preferably into a heat exchanger in order to reuse some of the heat energy of the steam.

[0035] According to a further embodiment of the first aspect, the second number of intermediate chambers is between 6 and 40, preferably 10 to 25, more preferably 12 to 20, such as 14.

[0036] The number of intermediate chambers may thus vary between any of the above numbers. The total number of chambers adds the inlet chamber and the outlet chamber to the above number. Some of the above prior art suggests a total of 16 chambers which may be considered normal.

[0037] According to a further embodiment of the first aspect, the upper cylindrical part comprises a cyclone for transporting particulate material from the upper cylindrical part to the lower cylindrical part.

[0038] In this way the particulate material which may accumulate in the upper cylindrical part may be returned to the lower cylindrical part.

[0039] The above object and further objects which are evident from the below detailed description are according to a second aspect of the present invention achieved by a method of drying bulk particulate material by providing an apparatus, the apparatus comprising:

a vessel defining a lower cylindrical part defining a first cross-sectional area being perpendicular to the length of the lower cylindrical part and an upper cylindrical part defining a second cross-sectional area being perpendicular to the length of the upper cylindrical part,
an inner cylindrical part centrally located within the upper cylindrical part and the lower cylindrical part of the vessel for establishing a first fluid path from the upper cylindrical part to the lower cylindrical part within the inner cylindrical part and a second fluid path from the lower cylindrical part to the upper cylindrical part outside the inner cylindrical part,
a first number of partitioning walls extending radially within the lower cylindrical part between the lower cylindrical part and the inner cylindrical part and defining in the lower cylindrical part an inlet chamber, an outlet chamber and a second number of intermediate chambers located between the inlet chamber and the outlet chamber in a circumferential direction, the inlet chamber comprising a inlet, the outlet chamber comprising an outlet, the inlet chamber and the intermediate chambers each defining a steam permeable bottom, the outlet chamber defining a non-steam permeable bottom, the steam permeable bottom of the inlet chamber being adapted to receive between 20% and 50% of the flow of superheated steam from the impeller, said inlet chamber being larger than any of the intermediate chambers and hereby occupy a larger circular sector of the ring-shaped space between the lower cylindrical part and the inner cylindrical part,
a heat exchanger located within the inner cylindrical part, and
an impeller,

the method comprising the steps of:

maintaining within the vessel a superheated steam at a pressure equal to or larger than the ambient pressure surrounding the vessel,
receiving moist bulk particulate material at the inlet,
heating the superheated steam within the heat exchanger,
generating a flow of superheated steam along the first fluid path from the upper cylindrical part through the heat exchanger within the inner cylindrical part to the lower cylindrical part via the steam permeable bottom, and along the second fluid path from the lower cylindrical part to the upper cylindrical part outside the inner cylindrical part, by using the impeller, and
ejecting dry bulk particulate material at the outlet.

[0040] It is evident that the method according to the second aspect may be used together with any of the apparatuses according to the first aspect.

Brief description of the drawings

[0041]

FIG. 1 illustrates a side sectional view of an apparatus for drying bulk particulate material, in particular drying of beet pulp.

FIG. 2 illustrates a perspective view of the lower cylindrical part of the apparatus.

FIG. 3 shows a top sectional view of the lower cylindrical part of the apparatus.

FIG. 4 illustrates a perspective view of a lower cylindrical part of an alternative embodiment of the apparatus.

FIG. 5 shows a top sectional view of the lower cylindrical part of the alternative embodiment of the apparatus.

Detailed description of the drawings

[0042] FIG. 1 shows a side sectional view of an apparatus 10 for drying bulk particulate materials, in particular drying of beet pulp. The apparatus 10 comprises a vessel 12 comprising a lower cylindrical part 14, an intermediate conical part 16 and an upper cylindrical part 18. The vessel 12 is closed off by a top 20 and a bottom 22. The vessel 12 further comprises an inner cylindrical part 24 extending within the vessel between the upper cylindrical part 18 and the lower cylindrical part 14. The inner cylindrical part 24 includes a heat exchanger (not visible) and defines a first fluid path from said upper cylindrical part 18 to said lower cylindrical part 14 within said inner cylindrical part 24 and a second fluid path from said lower cylindrical part 14 to said upper cylindrical part 18 outside said inner cylindrical part, as shown by the arrows.

[0043] The vessel 12 further comprises an inlet 26 constituting a screw conveyor for introducing moist particulate material into the lower cylindrical part 14 of the vessel 12 as shown by the arrow, and an outlet 28 constituting a screw conveyor for ejecting dry particulate material from the lower cylindrical part 14 of the vessel 12 as shown by the arrow. The inlet 26 is located above and circumferentially shifted relative to the outlet 28. A motor 30 is located below the vessel 12 for driving an impeller 32 located in the lower cylindrical part 14 below the inner cylindrical part 24. The impeller 32 generates a flow of superheated steam along the above mentioned fluid paths. A steam permeable bottom 34 is located above the impeller 32.

[0044] A number of partitioning walls 36 are radially extending between the lower cylindrical part 14 and the inner cylindrical part 24 and dividing the space between the lower cylindrical part 14 and the inner cylindrical part 24 into a number of chambers 38. The chamber located at the inlet 26 is designated inlet chamber 38' and the chamber located at the outlet 28 is designated outlet chamber 38". Typically, the inlet chamber 38' and the outlet chamber 38" are located adjacent each other, however, the particulate material should not be able to move directly from the inlet chamber 38' to the outlet chamber 38" without passing the intermediate chambers 38. The moist particulate material is received in the inlet chamber 38' on a fluid bed established by the flow of superheated steam above the steam permeable bottom 34. The partitioning walls 36 include whirling blades 40 for inducing a circumferential whirl for transporting the particulate material from the inlet chamber 38' to the outlet chamber 38" via the intermediate chambers 38 as shown by the arrows. The outlet chamber 38" has a non-permeable bottom which allows the dried particulate material to be ejected via the outlet 28 as shown by the arrow.

[0045] The upper cylindrical part 18 of the vessel 12 comprises guide blades 42 for generating a cyclone field in upper cylindrical part 18. The guide blades 42 will establish a whirling movement of the flow of superheated steam corresponding to the above mentioned circumferential whirl and force any particles outwardly which have been lifted from the lower cylindrical part 14 through the intermediate conical part 16 into the upper cylindrical part 18. The outwardly forced particles will be collected in a cyclone 44 and returned to the lower cylindrical part 14 as shown by the arrows. The superheated steam will be introduced into the inner cylindrical part 24 and be reheated by the heat exchanger before returning to the impeller 32. A small portion of the superheated steam will escape the vessel 12 via a centrally located steam exit 46. The superheated steam exiting the vessel 12 is subsequently cooled off via a heat exchanger.

[0046] The drying of the moist particulate material is effected on the fluid bed above the steam permeable bottom of the inlet chamber 38' and the intermediate chamber 38. Each chamber 38 may include further blades or similar means for establishing a whirling flow in the radial direction of the chamber 38. The whirling flow will increase the distribution of the particulate material within the chambers 38 and thereby increase the contact between the superheated steam and the particulate material, thereby increasing the vaporization of fluid from the particulate material and improving the drying.

[0047] FIG. 2 shows a perspective view of the lower cylindrical part 14 of the apparatus 10. The inlet chamber 38' is larger than the intermediate chambers 38 for allowing a larger portion of the superheated steam to enter the inlet chamber 38' compared to the intermediate chambers 38. In this way the heavy liquid containing particulate material entering the inlet chamber 38' may be distributed over a larger area, reducing the flow resistance and thereby both preventing clogging and improving the drying.

[0048] FIG. 3 shows a top sectional view of the lower cylindrical part 14 of the apparatus 10. The radial partitioning walls 36 define the circular sector shape of the chambers 38. The particulate material may move in a clockwise direction from the inlet chamber 38' to the outlet chamber 38" via all of the chambers by flowing above the partition wall 36 or through apertures 48 which may optionally exist in the partition wall 36. The steam permeable bottom 34 is shown having perforations 50 for allowing superheated steam to flow into the drying chambers.

[0049] FIG. 4 a perspective view of a lower cylindrical part 14 of an alternative embodiment of the apparatus designated 10'. Instead of making the inlet chamber 38' larger, the inlet chamber may be made as large as the intermediate chambers 38 and have a steam permeable bottom 34' allowing a larger portion of the superheated steam from the impeller (not shown) to pass compared to the intermediate chambers 38.

[0050] FIG. 5 shows a top sectional view of the lower cylindrical part 14 of the alternative embodiment of the apparatus 10'. As an example, the perforations 50 may be larger as shown in the present figure. Alternatively, there may be additional perforations. The additional superheated steam allows the inlet chamber 38' to produce additional lift overcoming the drag by the heavy liquid containing particulate material. The intermediate chambers 38 have less or smaller perforations 50 since the particulate material will be lighter and thereby less prone to clog.

[0051] As mentioned in the general part of the specification, ideally between 20% and 40% of the steam from the impeller and heat exchanger will be directed to the inlet chamber 38' for achieving an optimal distribution of the particulate material.

Reference numerals

[0052]

10. Apparatus for drying bulk particulate material
12. Vessel
14. Lower cylindrical part
16. Intermediate conical part
18. Upper cylindrical part
20. Top
22. Bottom
24. Inner cylindrical part
26. Inlet
28. Outlet
30. Motor
32. Impeller
34. Steam permeable bottom
36. Partitioning walls
38. Chambers
40. Whirling blades
42. Guide blades
44. Cyclone
46. Steam exit
48. Aperture
50. Perforations

Claims

1. An apparatus (10) for drying bulk particulate material, said apparatus comprising:

a vessel (12) capable of maintaining superheated steam at a pressure equal to or larger than the ambient pressure surrounding said vessel (12), said vessel (12) defining a lower cylindrical part (14) defining a first cross-sectional area being perpendicular to the length of the lower cylindrical part (14) and an upper cylindrical part (18) defining a second cross-sectional area being perpendicular to the length of the upper cylindrical part (18),
an inner cylindrical part (24) centrally located within said upper cylindrical part (18) and said lower cylindrical part (14) of said vessel (12) for establishing a first fluid path from said upper cylindrical part (18) to said lower cylindrical part (14) within said inner cylindrical part (24) and a second fluid path from said lower cylindrical part (14) to said upper cylindrical part (18) outside said inner cylindrical part (24),
a first number of partitioning walls (36) extending radially within said lower cylindrical part (14) between said lower cylindrical part (14) and said inner cylindrical part (24) and defining in said lower cylindrical part (14) an inlet chamber (38'), an outlet chamber (38") and a second number of intermediate chambers (38) located between said inlet chamber (38') and said outlet chamber (38") in a circumferential direction, said inlet chamber comprising a inlet for receiving a moist bulk particulate materials, said outlet chamber (38") comprising an outlet (28) for ejecting a dry bulk particulate materials, said inlet chamber (38') and said intermediate chambers (38) each defining a steam permeable bottom (34), said outlet chamber (38") defining a non-steam permeable bottom,
a heat exchanger located within said inner cylindrical part (24) for heating said superheated steam,
an impeller (32) for generating a flow of superheated steam along said first fluid path from said upper cylindrical part (18) through said heat exchanger within said inner cylindrical part (24) to said lower cylindrical part (14) via said steam permeable bottom (34), and along said second fluid path from said lower cylindrical part (14) to said upper cylindrical part (18) outside said inner cylindrical part (24), and
said steam permeable bottom (34) of said inlet chamber (38') being adapted to receive between 20% and 50% of said flow of superheated steam from said impeller (32),
said inlet chamber (38') being larger than any of the intermediate chambers (38) and hereby occupy a larger circular sector of the ring-shaped space between the lower cylindrical part (14) and the inner cylindrical part (24).

2. The apparatus (10) according to claim 1, wherein said inlet chamber (38') being adapted to receive between 22% and 45% of said superheated steam received from said inner cylindrical part (24), preferably between 25% and 40% of said superheated steam received from said inner cylindrical part (24), more preferably between 30% and 35% of said superheated steam received from said inner cylindrical part (24), such as 33% of said superheated steam received from said inner cylindrical part (24).

3. The apparatus (10) according to claim 1, wherein said inlet chamber (38') being adapted to receive between 20% and 22% of said superheated steam received from said inner cylindrical part (24), and/or between 22% and 25% of said superheated steam received from said inner cylindrical part (24), and/or between 25% and 30% of said superheated steam received from said inner cylindrical part (24), and/or between 30% and 35% of said superheated steam received from said inner cylindrical part (24), and/or between 35% and 40% of said superheated steam received from said inner cylindrical part (24), and/or between 40% and 45% of said superheated steam received from said inner cylindrical part (24), and/or between 45% and 50% of said superheated steam received from said inner cylindrical part (24).

4. The apparatus (10) according to any of the preceding claims, wherein said inlet chamber (38') and said intermediate chambers (38) each define a flow area being parallel with said first cross-sectional area, said flow area of said inlet chamber (38') being greater than said flow area of any of said intermediate chambers.

5. The apparatus (10) according to any of the preceding claims, wherein said partitioning walls (36) defining a first partitioning wall and a second partitioning wall both delimiting said inlet chamber (38') in said circumferential direction, said first partitioning wall and a second partitioning wall defining an angle them between of between 50° and 180°, preferably between 70° and 160, more preferably between 90° and 140°, such as 120°.

6. The apparatus (10) according to any of the preceding claims, wherein said steam permeable bottom (34) of said inlet chamber (38') defines a steam permeability of between 20% and 45% of the steam permeability of the total steam permeability of all of said steam permeable bottoms, preferably between 25% and 40%, more preferably between 30% and 35%, such as 33% .

7. The apparatus (10) according to any of the preceding claims, wherein said steam permeable bottoms of said inlet chamber (38') and said intermediate chambers (38) define perforations (50).

8. The apparatus (10) according to claim 7, wherein said perforations (50) of said steam permeable bottoms of said inlet chamber (38') define an area being 20% to 45% of the total area of all of said perforations of all of said steam permeable bottoms, preferably between 25% and 40%, more preferably between 30% and 35%, such as 33%.

9. The apparatus (10) according to any of the preceding claims, wherein said vessel (12) comprises an intermediate conical part (16) interconnecting said lower cylindrical part (14) and said upper cylindrical part (18) so that said second cross-sectional area is larger than said first cross-sectional area.

10. The apparatus (10) according to any of the claims 1-8, wherein said second cross-sectional is substantially equal to said first cross-sectional area.

11. The apparatus (10) according to any of the preceding claims, wherein all of said steam originates from said moist bulk particulate material.

12. The apparatus (10) according to any of the preceding claims, wherein said second number is between 6 and 40, preferably 10 to 25, more preferably 12 to 20, such as 14.

13. The apparatus (10) according to any of the preceding claims, wherein said upper cylindrical part (18) comprises a cyclone (44) for transporting particulate material from said upper cylindrical part (18) to said lower cylindrical part (14).

14. An method of drying bulk particulate materials by providing an apparatus (10), said apparatus comprising:

a vessel (12) defining a lower cylindrical part (14) defining a first cross-sectional area being perpendicular to the length of the lower cylindrical part (14) and an upper cylindrical part (18) defining a second cross-sectional area being perpendicular to the length of the upper cylindrical part (18),
an inner cylindrical part (24) centrally located within said upper cylindrical part (18) and said lower cylindrical part (14) of said vessel (12) for establishing a first fluid path from said upper cylindrical part (18) to said lower cylindrical part (14) within said inner cylindrical part (24) and a second fluid path from said lower cylindrical part (14) to said upper cylindrical part (18) outside said inner cylindrical part (24),
a first number of partitioning walls (36) extending radially within said lower cylindrical part (14) between said lower cylindrical part (14) and said inner cylindrical part (24) and defining in said lower cylindrical part (14) an inlet chamber (38'), an outlet chamber (38") and a second number of intermediate chambers (38) located between said inlet chamber (38') and said outlet chamber (38") in a circumferential direction, said inlet chamber (38') comprising an inlet (26), said outlet chamber (38") comprising an outlet (28), said inlet chamber (38') and said intermediate chambers (38) each defining a steam permeable bottom (34), said outlet chamber (38") defining a non-steam permeable bottom, said steam permeable bottom (34) of said inlet chamber (38') being adapted to receive between 20% and 50% of said flow of said superheated steam from an impeller (32), said inlet chamber (38') being larger than any of the intermediate chambers (38) and hereby occupy a larger circular sector of the ring-shaped space between the lower cylindrical part (14) and the inner cylindrical part (24),
a heat exchanger located within said inner cylindrical part, and
an impeller (32),

said method comprising the steps of:

maintaining within said vessel (12) a superheated steam at a pressure equal to or larger than the ambient pressure surrounding the vessel (12),
receiving moist bulk particulate material at said inlet (26),
heating said steam within said heat exchanger, generating a flow of superheated steam along said first fluid path from said upper cylindrical part (18) through said heat exchanger within said inner cylindrical part (24) to said lower cylindrical part (14) via said steam permeable bottom (34), and along said second fluid path from said lower cylindrical part (14) to said upper cylindrical part (18) outside said inner cylindrical part, by using said impeller (32), and ejecting dry bulk particulate material at said outlet (28).

15. The method according to claim 14, further comprising any of the features of the claims 1-13.

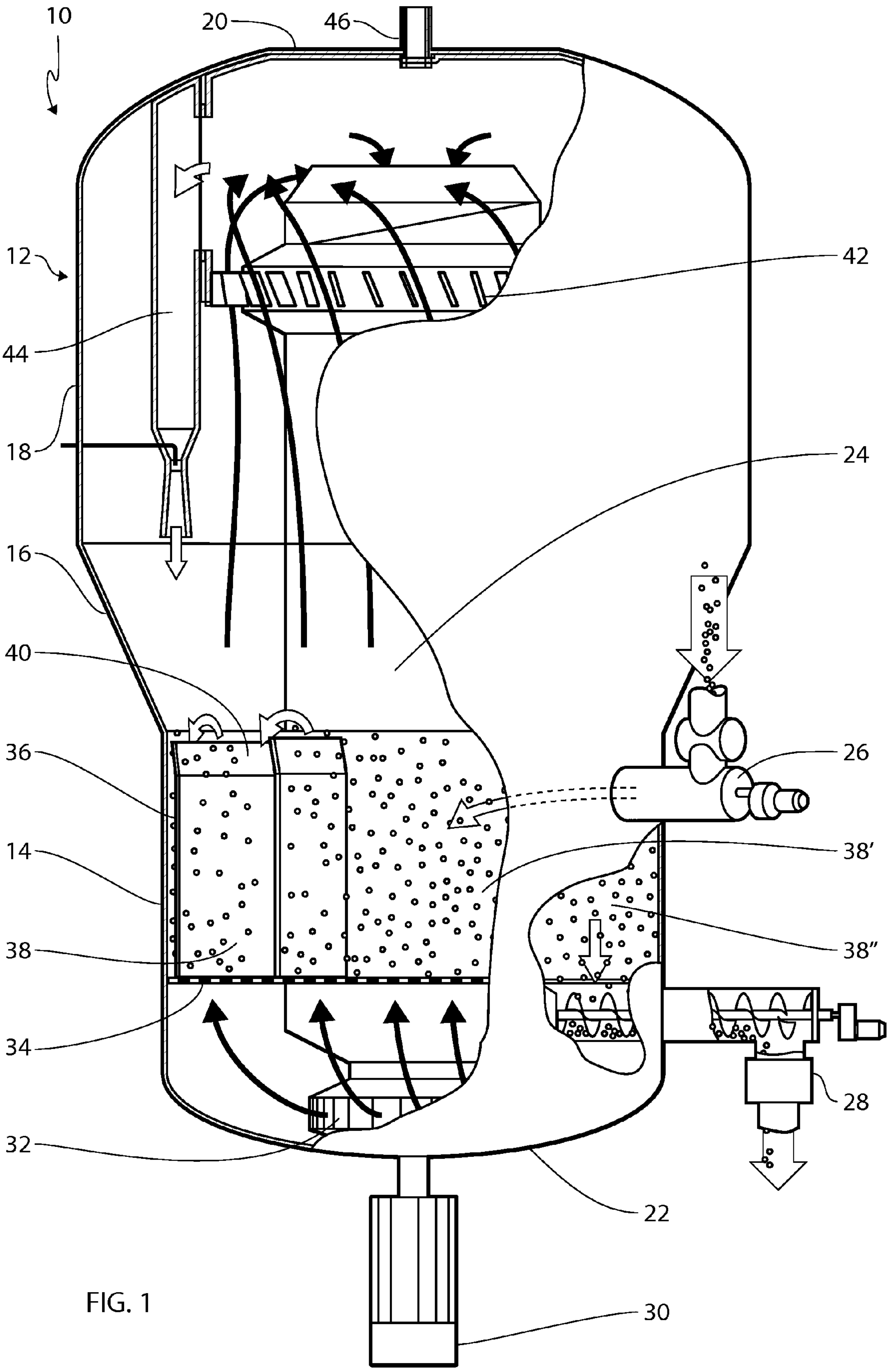

FIG. 1

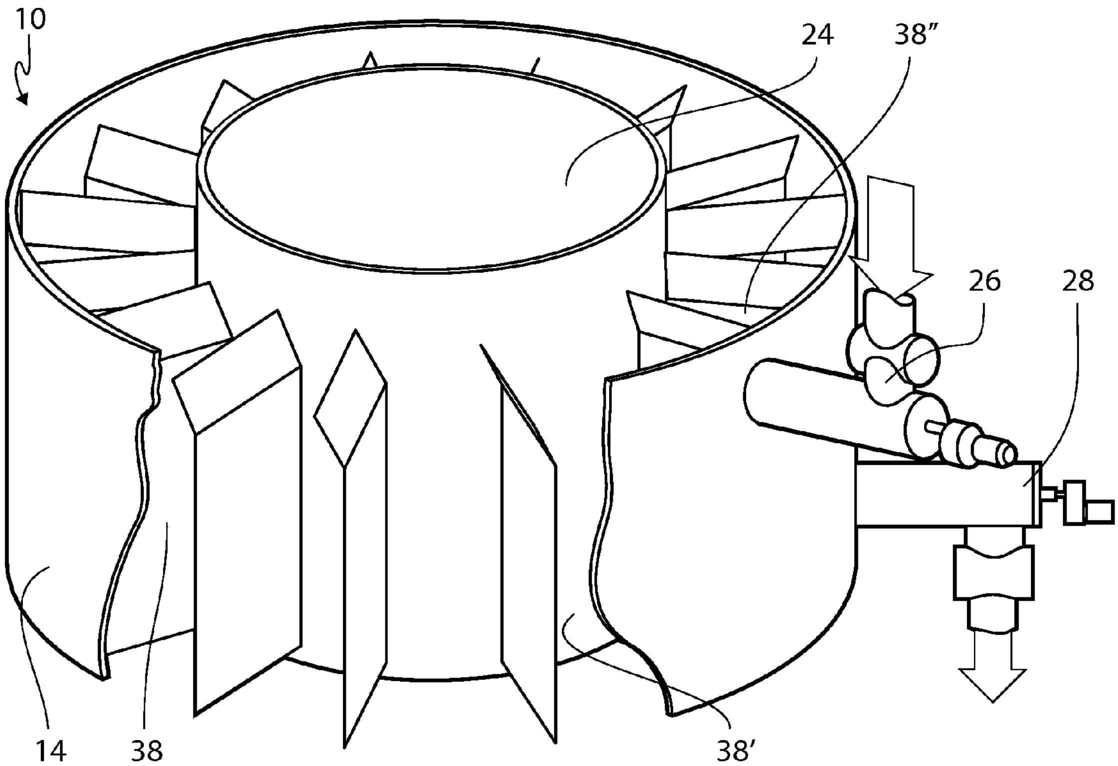

FIG. 2

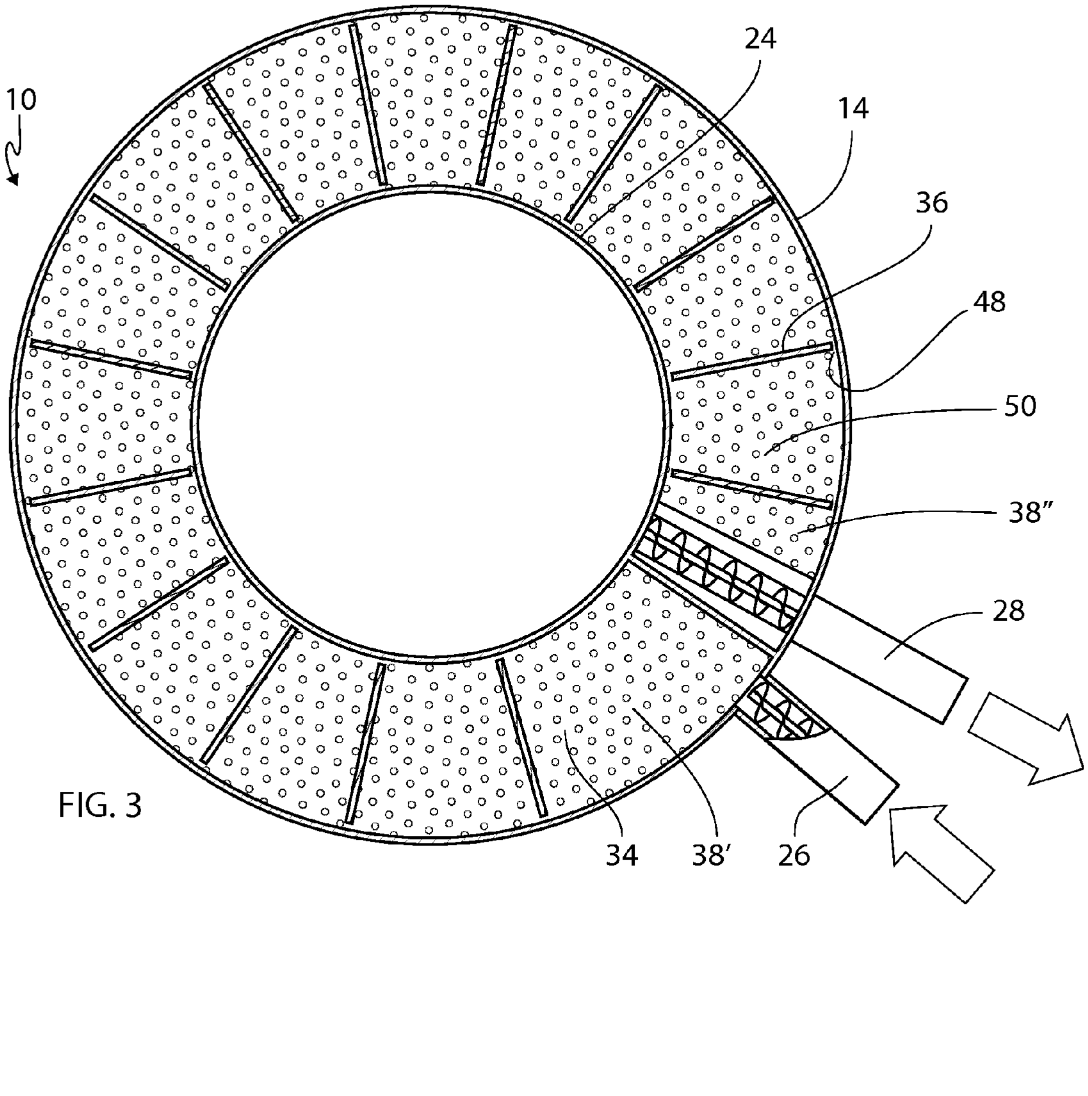

FIG. 3

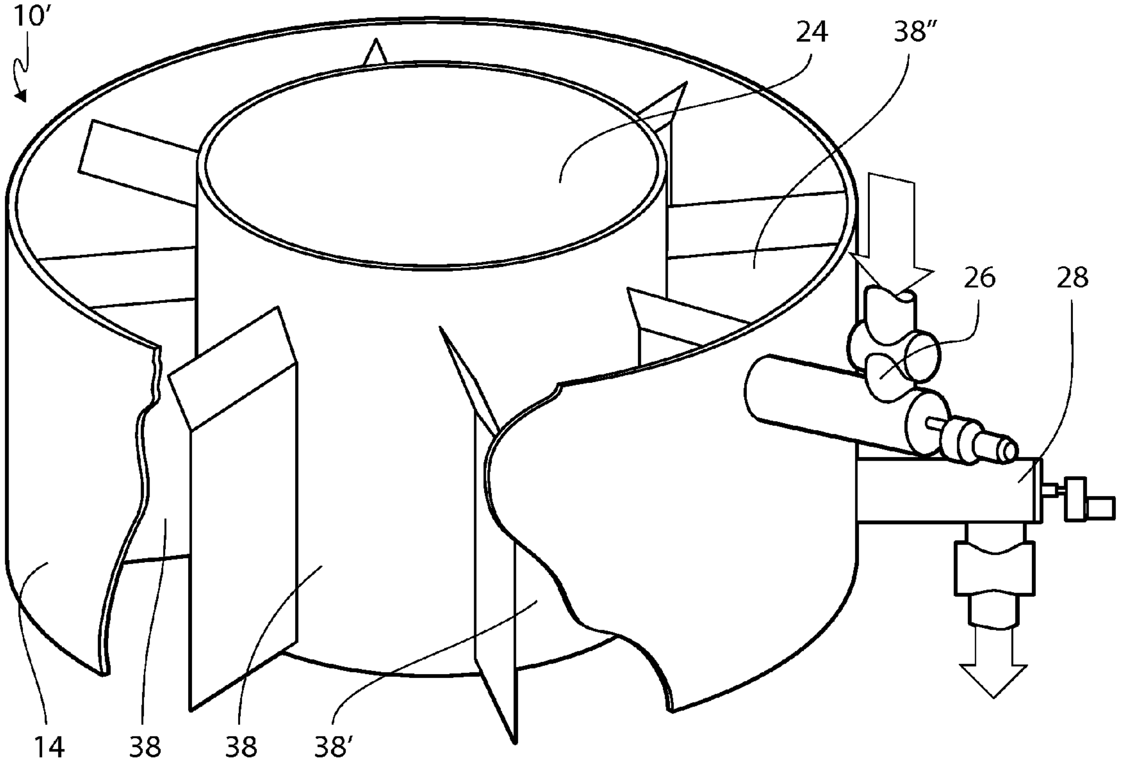

FIG. 4

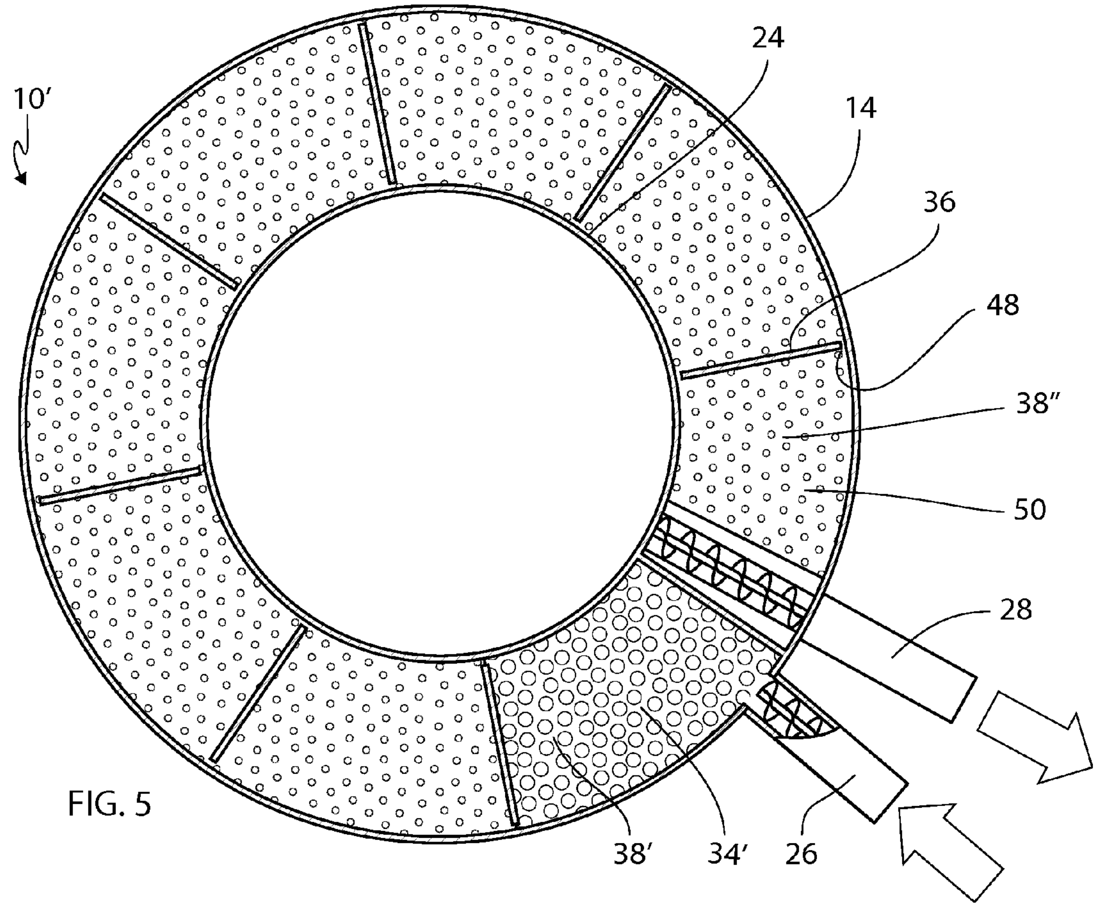

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 19 17 1293

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	30 August 2019	Villar Fernández, R

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