



(51) International Patent Classification:
F26B 3/06 (2006.01) *B01D 45/12* (2006.01)
B04C 5/28 (2006.01)

(21) International Application Number:
PCT/SE2010/050975

(22) International Filing Date:
13 September 2010 (13.09.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0950692-4 22 September 2009 (22.09.2009) SE

(71) Applicant (for all designated States except US):
SKELLEFTEÅ KRAFTAKTIEBOLAG [SE/SE]; Box
802, S-931 28 Skellefteå (SE).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **NÄSLUND, Bengt-Olof** [SE/SE]; Umedalsallén 31, S-903 64 Umeå (SE).

(74) Agent: **Albihns.Zacco AB**; P.O. Box 5581, Valhallavä-
gen 117, S-114 85 Stockholm (SE).

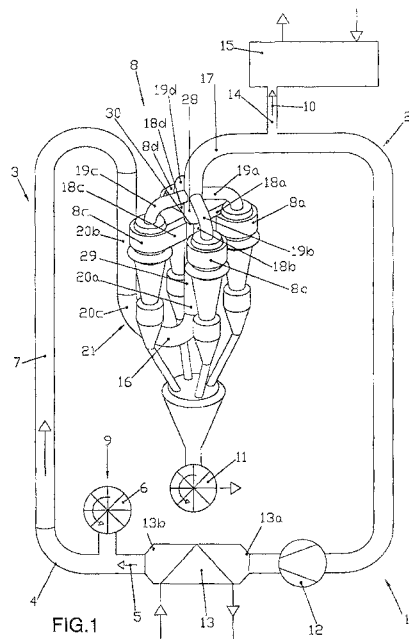
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) Title: DRYING APPARATUS AND PROCESS FOR DRYING BULK MATERIAL AND USE OF SAID DRYING APPARATUS TO DRY BULK MATERIAL.



(57) Abstract: The invention relates to a drying apparatus (1) for drying bulk material comprising -a closed circulation conduit (4) being adapted to be filled with a drying medium when said drying apparatus is in operation -a fan (12) connected into said closed circulation conduit for generating a flow of drying medium, -heating means (13) connected to the fan (12) for indirectly heating the drying medium, -inlet feeding means (6) connected to said closed circulation conduit (4) for feeding bulk material into the closed circulation conduit, -a drying enclosure (7) connected to the inlet feeding means (6) wherein said bulk material is dried by transfer of thermal energy from said drying medium, -separating means (8;8') connected to the drying enclosure (7) for separating bulk material from said drying medium, -a surplus steam outlet (14) connected to said closed circulation conduit (4) for releasing surplus steam (10), wherein said separating means (8) comprise a plurality of cyclones (8a-d;8'a-d). The present invention also relates to a process for drying bulk material using said drying apparatus and to the use of said drying apparatus to dry wood based bulk material or agricultural based bulk material. The present invention also relates to a combined heat and power plant comprising said drying apparatus.

**Drying apparatus and process for drying bulk material and use of said drying
apparatus to dry bulk material**

Field of invention

5 The present invention relates to a drying apparatus for drying bulk material according to the preamble of claim 1. The present invention also relates to a process for drying bulk material using said drying apparatus. The present invention also relates to a combined heat and power plant comprising said drying apparatus. The present invention also relates to the use of said
10 drying apparatus to dry wood based bulk material or agricultural based bulk material.

Background

Drying apparatus for drying bulk material are known where wet or moist feed stock is dried by a drying medium, normally a heated gaseous medium. A cyclone in the drying apparatus
15 separates the dried bulk material from the drying medium, where after the drying apparatus discharges the bulk material. Some prior art drying apparatus reheats and recycles the drying medium. However, insufficient separation of dried bulk material from the drying medium may give rise to accumulation of particles of the bulk material in the recycled drying medium. These particles and other derivable matters, such as lignin and tar from the particles, can accumulate in
20 the drying medium and may deposit on heat conducting surfaces in a heating means, which is disadvantageous for efficient heat transfer.

Summary of the invention

25 With the above description in mind, the object of this invention is to provide a drying apparatus wherein the separation of bulk material from the drying medium is improved and whereby at least some of the disadvantages of known technology are overcome.

The productivity and efficiency of the drying apparatus may thereby be increased and the cost and time for maintenance of the heating means in the drying apparatus may also be reduced.

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In accordance with the present invention, this and other objects, apparent from the following description, are achieved by a drying apparatus for drying bulk material according to claim 1. Said drying apparatus comprises a closed circulation conduit being adapted to be filled with a drying medium when said drying apparatus is in operation. The drying apparatus also comprises

- 2 -

a fan connected into said closed circulation conduit for generating a flow of drying medium and heating means connected to the fan for indirectly heating the drying medium. The drying apparatus also comprises inlet feeding means connected to said closed circulation conduit for feeding bulk material into the closed circulation conduit and a drying enclosure connected to said inlet feeding means wherein said bulk material is dried by transfer of thermal energy from said drying medium. The drying apparatus also comprises a surplus steam outlet connected to said closed circulation conduit for releasing surplus steam and separating means connected to the drying enclosure for separating bulk material from said drying medium, wherein said separating means comprises a plurality of cyclones.

As the drying apparatus comprises a separating means comprising a plurality of cyclones, each cyclone will receive only a part of the amount of flow of bulk material and drying medium. The size of the cyclones can therefore be reduced in comparison with the prior art single cyclone, which means that the pressure drop in each cyclone may be less and the centrifugal force on the bulk material may be higher than in the prior art single cyclone. As a result, even though the separation may be carried out in only one step, the separation efficiency and the efficacy of the drying apparatus can be substantially improved.

Another advantage of the present invention is that the utilization of a separating means comprising a plurality of cyclones in the drying apparatus results in less accumulation of particles in the drying medium. This means that less particles are recycled with the drying medium to the heater, consequently also less particles may be deposited on the heat conducting surfaces of the heater. A decrease in deposits of particles and derivable matters from the particles in the heating means greatly extends the operating periods and lowers the maintenance costs for cleaning and replacing parts of the heater.

Another advantage of the present invention is that the utilization of a separating means comprising a plurality of cyclones surprisingly results in a large reduction of pollutants in the effluents to the external waste water system. Pollutants such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) originate from suspended particles of bulk material in the waste condensate, which represent a large part of the effluents from the drying apparatus. The waste condensate is generated in the energy recovery process where latent heat in surplus steam released from the drying apparatus is recovered. The drying apparatus of the present invention significantly reduces the amount of particles of bulk material in the surplus steam,

consequently the amount of particles in the waste condensate is also considerably reduced.

In accordance with the present invention, the above mentioned object and other objects apparent from the following description are also achieved by a process for drying bulk material in
5 a drying apparatus according to the present invention, where said drying apparatus comprising a closed circulation conduit filled with a drying medium when the drying apparatus is in operation and which process comprises generating a flow of said drying medium by a fan inside said closed circulation conduit and indirectly heating said drying medium by heating means. The process also comprises feeding bulk material by inlet feeding means into a flow of said drying
10 medium inside said closed circulation conduit, and drying said bulk material in a drying enclosure by transfer of thermal energy from said heated drying medium into said bulk material. Said process also comprises releasing surplus steam via a surplus steam outlet from said closed circulation conduit and separating said bulk material from said drying medium by a separating means comprising a plurality of cyclones.

15 Furthermore, there is also disclosed a combined heat and power plant comprising a drying apparatus according to the present invention. Also disclosed is the use of a drying apparatus according to the present invention to dry wood based materials. Furthermore, also the use of a drying apparatus according to the present invention to dry agricultural based materials is
20 disclosed.

A better understanding of the present invention will be had upon the reference to the following detailed description when read in conjunction with the accompanying drawings, wherein like reference characters refer to like parts throughout several views, and in which:

25 Figure 1 illustrates a schematic process scheme of a the drying apparatus according to the invention having a first variant of separating means.

Figure 2 illustrates a second variant of separating means of the drying apparatus according to
30 the invention.

Figure 3 illustrates a length sectional view of the first variant of separating means shown in figure 1.

Figure 4a illustrates a schematic cross sectional view of the first variant of separating means

with three cyclones.

Figure 4b illustrates a schematic cross sectional view of the first variant of separating means with six cyclones.

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Figure 5 illustrates schematic process scheme for a combined heat and power plant integrated with a fuel factory with a drying apparatus according to the invention.

Detailed description of preferred embodiments

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In this specification 'bulk material' has a broad meaning which includes any moist or wet solid organic particulate bulk material with a size distribution and particle density suitable for pneumatic transport. The particulate bulk material particularly includes biomass derived from plants and animals. Examples include agricultural residues and wastes (stalks, straw etc), wood based raw materials (wood chips, bark, splinters and wood shavings), forest residues; sawmill wastes (saw dust), peat, energy crops and livestock wastes (from dairy, hog and poultry farms). The particulate bulk material also includes biomass based on residues from the food industry. These particulate bulk materials usually have an initial moisture content of at least 40% moisture on a weight basis. Similarly, 'steam' has a broad meaning which includes aqueous vapour, an oxygen free gaseous medium and mixtures thereof. Furthermore, 'drying medium' has a broad meaning which includes dry, wet, saturated, heated or superheated steam and combinations thereof.

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With reference to figure 1 a drying apparatus 1 for drying bulk material 9 according to an aspect of the invention is illustrated which comprises a heating section 2 and a drying section 3 connected to each other to substantially form a closed circulation conduit 4. In operation of the drying apparatus 1, the closed circulation conduit 4 is filled with a heated drying medium 5 such as heated wet steam or superheated saturated steam, thereby forming an oxygen free, inert, internal environment which inhibits the risk of dust explosions. The closed circulation conduit 4 comprises conduits and ducts for conducting bulk material suspended in drying medium between the elements of the drying apparatus.

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One purpose of the drying medium is to transfer thermal energy into the bulk material, another purpose of the drying medium is to convey, by means of pneumatic transport, bulk material

through said drying section 3 from inlet feeding means 6 to separating means 8.

The drying section 3 comprises inlet feeding means 6, a drying enclosure 7 and separating means 8. The inlet feeding means 6, such as an inlet feeder, is connected into the closed circulation conduit 4 downstream of the heating section 2 in relation to the direction of the flow of drying medium inside the closed circulation conduit 4. The inlet feeding means 6 feeds moist or wet bulk material 9 into said closed circulation conduit 4 wherein a flow of drying medium is circulated. Feeding may be carried out semi-continuously or continuously. The inlet feeder 6 is preferably a cellular feeder, a plug screw feeder or a similar feeding device providing a marginal drying medium leakage at the actual differential pressure thereby being adapted to avoid pressure loss from the closed circulation conduit of the drying apparatus. A drying enclosure 7 such as a drying conduit, a rotary drum or a fluid bed is connected to and downstream of the inlet feeder 6. Drying of the wet or moist bulk material 9 is carried out by mixing the bulk material and the heated drying medium 5 in the drying enclosure 7 whereby thermal energy is transferred from said heated drying medium into the particles of said bulk material. Moisture and volatiles in the particles of the wet bulk material 9 vaporizes and forms surplus steam 10. Drying is carried out at steady state conditions, meaning fully developed pneumatic transport of said bulk material 9 by the drying medium 5 through the drying enclosure 7.

The dried bulk material 9 suspended in the drying medium is conducted in the closed circulation conduit 4 to separating means 8 connected to and downstream of the drying enclosure 7 in relation to the direction of the flow of drying medium inside the closed circulation conduit. The separating means 8 comprise a plurality of cyclones which can separate the dried bulk material from the drying medium in one single separation step.

The separating means 8 is further described below. The separated bulk material is discharged from the drying apparatus 1 via an outlet feeder 11, and the drying medium is returned to the heating section 2.

The heating section 2 comprises a fan 12, a heater 13 and a surplus steam outlet 14. The fan 12 generates a flow of drying medium 5, said conveying steam, which circulates in the closed circulation conduit 4. A first end of the heater, indicated by 13a, is connected to the fan 12. The heater 13 indirectly heats or superheats the drying medium. The heater comprises a heat exchanger and is supplied by primary heat from flue gas, pressurized steam, hot water, thermal

oil or similar from a heat source. In particular industrial processes using steam, for example a combined heat and power plant, a paper mill, a steam generation plant or similar can supply heat to the drying apparatus 1.

5 A second end of the heater, indicated by 13b, is connected to the drying section 3 in the closed circulation conduit 4. Furthermore, the heating section 2 comprises a surplus steam outlet 14 which releases the surplus steam 10 evaporated from the particles in the bulk material in the drying process. Thereby the operating conditions, such as the pressure and the temperature, of the drying apparatus 1 may be controlled and maintained.

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The heating section 2 is connected downstream of the separating means 8 in relation to the direction of the flow of drying medium inside the closed circulation conduit. Consequently only the drying medium is conducted through the fan 12 and the heater 13. The bulk material 9 is only conveyed through the drying section 3 and bypasses the heating section 2. Since the
15 temperature of the drying medium inside the heater 13 is well above the softening temperature of lignin, it has to be avoided that particles of the bulk material are conveyed with the drying medium to the heater. The particles and derivable matters like lignin and tars may otherwise easily be released and deposit on the surfaces in the heating section 2 and particularly on the heat conducting surfaces of the heater 13. The efficiency of the heating means depends on the
20 transfer of thermal energy from the heat conducting surface of the heating means to the drying medium, if the heat conducting surfaces are not clean, the transfer of thermal energy to the drying medium decreases.

The surplus steam outlet 14 is connected downstream of the separating means 8 in relation to
25 the direction of the flow of drying medium inside the closed circulation conduit. The surplus steam 10 may be fed to energy recovery means 15, such as a steam regenerator or condenser as part of an energy recovery process. In the energy recovery means 15, the surplus steam is cooled and depleted of energy, whereby clean steam and waste condensate is generated. The waste condensate contains in particular condensed volatiles but may also contain suspended
30 particles of bulk material which have not been separated from the drying medium by the separating means 8. The suspended particles of bulk material in the waste condensate may give rise to pollutants like biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in the effluents from the drying apparatus. The environmental laws regarding effluents from industries are becoming increasingly stricter and demands careful supervision and control of the

levels of pollutions in industrial effluents. However, since the separating means 8 has proven to be very efficient, the environmental load from the drying apparatus and drying process is very limited. A surprising effect of utilizing the separating means 8 in the drying apparatus of the present invention is that generally no subsequent waste water treatment of the waste
5 condensate is necessary, since the level of amount of suspended particles in the waste condensate is insignificant or at least well below the permissible limits.

The dried bulk material discharged from the drying apparatus 1 may be used in further industrial applications such as fuel in a combustions chamber in a combined heat and power plant or in
10 the production of wood based panels like MDF or in the production of bio fuel pellets for the consumers market.

In particular when the feedstock is originating from wood or forest products, the energy content in the dried material is high and can be used for production of bio fuel pellets or be used as fuel in a combined heat and power plant supplying the drying apparatus with primary heat. By
15 varying the pressure and temperature inside the drying apparatus 1 and by adjusting the volume of wet bulk material fed to the drying apparatus, different characteristics of the final product can be achieved. For example, the bulk material can be dried to very low moisture content. In case the dried bulk material is to be used in the production of bio fuel pellets, the moisture content should be below 12 % by weight. Another application of the dried bulk material is in the
20 production of wood polymer composites. In such case the moisture content should be below 2% by weight, preferably below 1% by weight, most preferably below 0,5 % by weight.

In the following, several variants of separation means are described, each of which can be integrated in the drying apparatus described above. Furthermore, all like features are referred to
25 with like references.

Figure 1 further illustrates a first variant of the separating means 8. The separating means 8 comprise a plurality of cyclones. This means that the separation means 8 comprises at least two cyclones. In the drying apparatus illustrated in figure 1 the first variant of separating means 8
30 comprises four cyclones 8a-d of uniform size and configuration. It is however possible to vary the number of cyclones in accordance with the volume and type of bulk material to be dried.

The plurality of cyclones 8a-d in the separating means 8 are connected via a common inlet passage 16 to the drying enclosure 7. The cyclones 8a-d are also connected via a common gas

- 8 -

outlet passage 17 to the fan 12. The flow of suspended bulk material 9 and drying medium 5 is thereby conducted from said drying enclosure 7 via said common inlet passage 16 concurrently to all of said plurality of cyclones 8a-d and the drying medium 5 is discharged concurrently from all of said plurality of cyclones 8a-d via a common gas outlet passage 17 to said fan 12. This has the advantage that the separation of said bulk material 9 from said drying medium takes place before the drying medium is returned to the heating section, where suspended particles otherwise could deposit on the surfaces of the fan 12 and the heater 13.

The plurality of cyclones 8a-d are preferably connected in parallel via cyclone inlet ducts 18a-d to said common inlet passage 16. Furthermore the plurality of cyclones 8a-d are preferably also connected in parallel via gas outlet ducts 19a-d to said common gas outlet passage 17. Said flow of bulk material and drying medium is thereby distributed concurrently to the plurality of cyclones connected in parallel via said cyclone inlet ducts 18a-d and the drying medium is discharged concurrently from the plurality of cyclones connected in parallel via said gas outlet ducts 19a-d. One functional advantage of this is that the flow of bulk material and drying medium is shared between the plurality of cyclones, which results in that each cyclone only receives a part of the entire flow. Consequently the dimensions of the cyclones may be reduced and the cyclonic separation efficiency is improved.

The common inlet passage 16 comprises a vertical inlet segment 20a and the plurality of cyclones 8a-d are preferably symmetrically arranged around said vertical inlet segment 20a. The plurality of cyclones 8a-d are preferably equidistantly arranged in relation to said vertical inlet segment 20a of said common inlet passage 16. One functional advantage of this is that an equal distribution of the flow of bulk material and drying medium conveyed into the cyclones may be achieved.

The common inlet passage 16 is connected to each cyclone 8a-d via a cyclone inlet duct 18a-d to distribute the flow of bulk material and drying medium into the cyclones. Preferably each cyclone is connected to said vertical inlet segment 20a of the common inlet passage 16 via its own cyclone inlet duct 18a-d. Preferably the cyclone inlet ducts are as short as possible to limit the flow resistance, however the length of the cyclone inlet ducts may be adapted to the circumstances. Preferably all cyclone inlet ducts 18a-d have equal cross sectional area to achieve an equivalent volume of flow through each respective cyclone.

In figure 1 it is shown that the common inlet passage 16 comprises a U-shaped conduit 21

connected in between the drying enclosure 7 and the separation means 8. Said U-shaped conduit 21 comprises two vertical segments 20a, 20b and a curved segment 20c connecting said vertical segments 20a, 20b in their lowermost end. One of the vertical segments 20a is disposed in the center between the four cyclones 8a-d. However, the common inlet passage 16
5 can alternatively comprise a conduit having a horizontal segment, a curved segment and a vertical segment, wherein the horizontal segment is connected to the drying enclosure 7(not shown in figure).

In the drying apparatus shown in figure 1 the first variant of separating means 8 comprises four
10 cyclones 8a-d. In operation of the drying apparatus comprising a separating means 8 of four cyclones 8a-d one fourth of the amount of flow of suspended bulk material and drying medium is distributed into each cyclone 8a-d. As previously mentioned, the separating means 8 may be configured with a different number of cyclones. The amount of flow distributed into each of the cyclones vary in a corresponding way. For example, if the separating means 8 comprises five
15 uniform cyclones, each cyclone will receive one fifth of the amount of flow.

For a given total flow rate of suspended bulk material and drying medium, the pressure drop in each cyclone 8a-d is less and the centrifugal force applied to the particles of the bulk material during cyclonic separation is stronger in comparison with the prior art single cyclone since the
20 size of each of the cyclones, the width, diameter and height, can be reduced in comparison with the prior art single cyclone. As a result, even though the separation may be carried out in only one step, the separation efficiency can be improved.

Figure 3 illustrates a length sectional of the first variant of separating means 8. In fig 3 it is
25 indicated by means of an arrow that the flow of bulk material 9 and drying medium is pneumatically conveyed upwards in a vertical direction in the vertical inlet segment 20a of the common inlet passage 16 to the cyclone inlet ducts 18a-d. By conveying the suspended bulk material by aid of pneumatic transport vertically upwards, against gravitation, the distribution of the particles of the bulk material is improved and a more even distribution of the particles in the
30 drying medium is achieved. This has the functional benefit that the particles of said bulk material are spread more evenly in the drying medium and as a consequence a more even distribution into the plurality of cyclones 8a-d is achieved. An equal distribution of bulk material and drying medium conveyed into each of the cyclones may be achieved. The bulk material suspended in drying medium is conducted by the common inlet passage 16 and distributed, apportioned, into

- 10 -

the cyclones 8a-d via the cyclone inlet ducts 18a-d. The common inlet passage 16 comprises a baffle 22 to divert the suspended bulk material into the cyclone inlet ducts 18a-d.

Furthermore, in figure 3 it is also shown that each cyclone 8a-d comprises a cyclone top section 23, a cyclone separation section 24 and a cyclone collecting section 25. The cyclone top section 23 has a cylindrical cross section. The cyclone inlet duct 18a-d is disposed perpendicular to said common inlet passage 16, and connected tangentially to the cyclone top section 23 to tangentially introduce the flow of bulk material into the cyclone to achieve efficient cyclonic separation. Each cyclone collecting section 25 respectively is connected to a central hopper 26 via discharge pipes 27. The cyclones are thereby connected in parallel also to the central hopper. The outlet feeder 11 is connected to the central hopper 26 to discharge the separated dried bulk material from the drying apparatus 1. The outlet feeder 11 is of a similar type as the inlet feeder 6 mentioned above.

The common gas outlet passage 17 also comprises a vertical outlet segment 28, and said cyclones 8a-d are preferably symmetrically arranged in relation to said vertical outlet segment 28 of said common gas outlet passage 17. Each cyclone 8a-d is connected to said common gas outlet passage 17 via a gas outlet duct 19a-d to discharge the separated drying medium 5 from each cyclone. Said gas outlet ducts 19a-d are preferably symmetrically disposed around the common gas outlet passage 17 and connected thereto.

Preferably each cyclone is connected to said common gas outlet passage 17 via its own gas outlet duct 19a-d. The drying medium 5 is returned to the heating section 2 by the fan 12 and further conveyed to the heater 13 for reheating.

Figure 1 and 3 also shows a common conduit 29 located in the center between the four cyclones 8a-d disposed equidistantly from the common conduit 29. Said common conduit comprises the common inlet passage 16 and the common gas outlet passage 17. The vertical inlet segment 20 of the common inlet passage 16 and the vertical outlet segment 28 of the common gas outlet passage 17 are connected together, joined, to form a single united common conduit 29 with a separating cross-sectional divider 30 to divide said common conduit into said common inlet passage 16 and said common gas outlet passage 17. The structural benefit of this is to achieve a compact design and improve the supporting structure for the common inlet passage and the common gas outlet passage. In figure 3 the divider 30 is shown which comprises a divider inlet

side 31 adjacent the common inlet passage 16 and a divider outlet side 32 adjacent the common gas outlet passage 17. Said divider inlet side 31 comprises a baffle 22 to divert the flow of bulk material and drying medium into said cyclone inlet ducts. The divider 30 and the baffle 22 are provided with flat surfaces since the pressure on the divider inlet side 31 and the divider outlet side 32 is almost identical.

As mentioned above, the number of cyclones may vary in the separating means 8. For example the separating means 8 may comprise two, three, four, five, six or more cyclones connected together in a corresponding manner as described above.

In figure 2 a second variant a separating means 8' is shown which differs from the previously described separating means 8 in that there is no direct connection between the common inlet passage 16 and the common gas outlet passage 17. Instead the common inlet passage 16 and the common gas outlet passage 17 are independently and separately arranged to allow for a flexible positioning of the cyclones. In figure 2 is further shown a plurality of cyclones 8'a-d having the same characteristics and effects as the cyclones 8a-d in the previously described separating means 8. The conduit end 50 of the common inlet passage 16 is provided with a baffle 22' directed towards the inside of the conduit to direct the flow of suspended bulk material into the cyclones. In the separating means 8' the conduit end 50 and the baffle surface 22' may be flat or have a curved shape, for example half spherical. This is particularly advantageous if there is a pressure difference between the inside and the outside of the conduit end 50.

Apart from the above mentioned differences, all other features of the second variant of a separating means 8' have the same characteristics and effects as the corresponding features in the previously described separating means 8, and are therefore not further described. Furthermore the second variant of separating means 8' may be connected into a drying apparatus 1 in a corresponding manner as the first separating means 8.

The design of the separating means 8, 8' and the number of cyclones can differ from the above described embodiments without parting from the scope of the invention. The separation means 8 comprises at least two cyclones, alternatively the separation means 8 may comprise three, four, five, six or more cyclones connected in parallel to the common inlet passage 16 and connected in parallel to the common gas outlet passage 17. In figure 4a a schematic illustration is shown of the first variant of separating means with three cyclones 8a-c. In figure 4b another schematic

- 12 -

illustration is shown of the first variant of separating means 8 with six cyclones 8a-f. Also separating means 8' may comprise for example two, three, four, five, six or more cyclones. As the skilled person readily understands, also in the separating means 8' the cyclones may be connected into the drying apparatus in a corresponding manner as described above.

- 5 Adaptations of the drying apparatus 1 in respect of the positions and connections according to the number of cyclones fall within the scope of invention.

Any type of indirectly heated drying apparatus can be used such as a pneumatic dryers, fluid bed dryers or rotary drum dryers. The drying apparatus 1 may be a pressurized steam dryer.

- 10 Such a dryer may be operated above atmospheric pressure. Alternatively the drying apparatus 1 can also be operated at atmospheric pressure or below atmospheric pressure. The advantage of operating the dryer above atmospheric pressure is that the thermal energy is more efficiently recovered by the energy recovery process. This means that the drying apparatus 1 is operated at a positive pressure relative the atmospheric pressure. The pressure range is typically from 1
15 to 40 bars, preferably from 2 to 15 bars, more preferably from 2 to 10 bars, most preferably from 3 to 5 bars. Since the closed circulation conduit 4 of the drying apparatus 1 is filled with pressurized steam, the oxygen level is insignificant whereby the risk of dust explosions or fire is eliminated. The possibilities to utilize the vast heat source by recovering the latent heat in the surplus steam increases with the temperature i.e. with the pressure in the drying apparatus 1.
20 Additionally, the heat capacity of the steam increases with pressure level making it possible to reduce the dimensions of the drying apparatus.

The drying apparatus 1 may be used for drying wood based bulk material, agricultural based bulk material and all other materials mentioned in the description above.

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- The thermal energy from the drying apparatus 1 may be recovered in an energy recovery process by depleting the surplus steam 10 through indirect heat transfer to a different medium in a recovery means 15 connected to the drying apparatus 1. Different recovery means 15 can be used depending on the geographical location of the drying apparatus 1 but also depending on
30 the purpose of the final dried product, other related industrial processes etc. In areas where district heating is available, the recovered heat can be used for feeding such a network. Recovery means 15 can for example be a steam regenerator for condensing steam, a heat exchanger producing low pressure steam where the low pressured steam can be used in a low pressure steam turbine for producing power or a district heating net. Another possibility is to

deliver the lower pressure steam to an external industrial process such as a saw mill or similar where the steam can be used in a very efficient manner in for example wood drying facilities. These are different non limiting examples for recovering the heat from the drying apparatus. If the recovery means 15 is a steam regenerator, combustible substances from the surplus steam may be separated by condensation, where after the combustible substances are combusted in a combustion chamber. The heat produced by combustion may be recovered by a steam turbine and returned as primary heat to the drying apparatus 1. However also other industrial applications are possible, such as integration with a paper or pulp factory, chemical industry or heavy industry like steel industry. In principle any type of steam generating process is combinable with the drying apparatus of the present invention.

Figure 5 shows a schematic process scheme of an advantageous and energy efficient combined heat and power plant (CHP) 36 which comprises a fuel factory 33 and the drying apparatus 1 according to the invention. The drying apparatus 1 is integrated in the fuel factory 33 which produces energy pellets of the dried bulk material. In addition to the drying apparatus, the fuel factory 33 also comprises a steam regenerator 34, for example a steam heat exchanger for converting the generated surplus steam 10 to low pressure process steam and/or to produce district heating. The fuel factory 33 also comprises a low pressure condensing turbine 35 for producing power which can be fed to the grid. A drying apparatus of this kind, typically a pressurized steam dryer, can have a production volume of more than 400 tons of bulk material per day (mainly wood chips, saw dust and forest residues) and flow speed of more than 20 m/s, which demand very large sized elements of the drying apparatus.

The combination of a combined heat and power plant and a fuel factory is particularly beneficial since a part of the fuel produced in the fuel factory can be supplied to the combined heat and power plant. The combined heat and power plant 36 comprises a combustion chamber 38 and a steam boiler 37 for steam generation. The generated steam is supplied to at least one turbine 39 for power generation. The steam is led from the turbine 39 to a heat condenser 40 which can supply a district heating net 41. Furthermore, extraction steam from the turbine at a pressure level between 5-40 bars supplies the drying apparatus 1 with the primary heat required for drying of bulk material by the indirect heating means 13 of the drying apparatus 1. This results in a very efficient combined energy plant producing power, heat and fuel.

- 14 -

Claims

1. A drying apparatus (1) for drying bulk material comprising
-a closed circulation conduit (4) being adapted to be filled with a drying medium when said
5 drying apparatus is in operation
-a fan (12) connected into said closed circulation conduit for generating a flow of drying medium,
-heating means (13) connected to the fan (12) for indirectly heating the drying medium,
-inlet feeding means (6) connected to said closed circulation conduit (4) for feeding bulk material
into the closed circulation conduit (4),
10 -a drying enclosure (7) connected to the inlet feeding means (6) wherein said bulk material is
dried by transfer of thermal energy from said drying medium,
-a surplus steam outlet (14) connected to said closed circulation conduit (4) for releasing surplus
steam (10),
-separating means (8;8') connected to the drying enclosure (7) for separating bulk material from
15 said drying medium,
characterized in that said separating means (8;8') comprises a plurality of cyclones (8a-d;8'a-d).
2. The drying apparatus of claim 1 wherein said plurality of cyclones (8a-d;8'a-d) are connected
via a common inlet passage (16) to the drying enclosure (7) and wherein said plurality of
20 cyclones are connected via a common gas outlet passage (17) to the fan (12).
3. The drying apparatus of claim 1 or 2 wherein said plurality of cyclones (8a-d;8'a-d) are
connected in parallel via cyclone inlet ducts (18a-d) to said common inlet passage (16).
- 25 4. The drying apparatus of any preceding claims wherein said plurality of cyclones (8a-d;8'a-d)
are connected in parallel via gas outlet ducts (19a-d) to said common gas outlet passage (17).
5. The drying apparatus of any preceding claim wherein said common inlet passage (16)
comprises a vertical inlet segment (20a) and said plurality of cyclones (8a-d;8'a-d) are
30 symmetrically arranged around said vertical inlet segment (20a).
6. The drying apparatus of any preceding claim wherein said common gas outlet passage (17)
comprises a vertical outlet segment (28), and said plurality of cyclones (8a-d;8'a-d) are
symmetrically arranged in relation to said vertical outlet segment (28) of said common gas outlet

passage (17).

7. The drying apparatus of any preceding claim wherein the plurality of cyclones (8a-d) are equidistantly arranged in relation to the common inlet passage (16).

5

8. The drying apparatus of any preceding claim comprising a common conduit (29), said common conduit comprising said common inlet passage (16) and said common gas outlet passage (17).

10 9. The drying apparatus of claim 8 wherein said common conduit (29) comprise a divider (30) to divide said common conduit (29) into said common inlet passage (16) and said common gas outlet passage (17).

15 10. The drying apparatus of any preceding claim wherein said plurality of cyclones comprises at least two, three, four, five or six cyclones.

11. The drying apparatus of any preceding claim wherein said drying apparatus (1) comprises a pressurized steam dryer working above atmospheric pressure.

20 12. A combined heat and power plant (36) comprising a drying apparatus (1) according to any preceding claim.

13. A process for drying bulk material in a drying apparatus (1) according to any of claims 1-11 comprising a closed circulation conduit (4) filled with a drying medium when the drying apparatus
25 is in operation, which process comprises

-generating a flow of said drying medium by a fan (12) inside said closed circulation conduit (4),

- indirectly heating said drying medium by heating means (13),

-feeding bulk material by inlet feeding means (6) into a flow of said drying medium inside said closed circulation conduit,

30 -drying said bulk material in a drying enclosure (7) by transfer of thermal energy from said heated drying medium into said bulk material,

-releasing surplus steam (10) via a surplus steam outlet (14) from said closed circulation conduit, said process characterized in separating said bulk material from said drying medium by a separating means (8;8') comprising a plurality of cyclones (8a-d,8'a-d).

- 16 -

14. The process of claim 13 comprising conducting a flow of bulk material and drying medium from said drying enclosure (7) via a common inlet passage (16) to said plurality of cyclones (8a-d; 8'a-d) and discharging the drying medium from said plurality of cyclones (8a-d; 8'a-d) via
5 a common gas outlet passage (17) to said fan (12).

15. The process of claims 13 or 14 comprising distributing said flow of bulk material and drying medium in parallel via cyclone inlet ducts (18a-d) into said plurality of cyclones (8a-d; 8'a-d).

10 16. The process of any of claims 13-15 comprising discharging the drying medium in parallel via gas outlet ducts (19a-d) from the plurality of cyclones (8a-d).

17. The process of any of claims 13-16 comprising conveying said flow of bulk material and drying medium upwards in a vertical direction in a vertical inlet segment (20a) of said common
15 gas inlet passage (16).

18. Use of a drying apparatus (1) according to any of claims 1-11 to dry wood based bulk material.

20 19. Use of a drying apparatus (1) according to any of claims 1-11 to dry agricultural based bulk material.

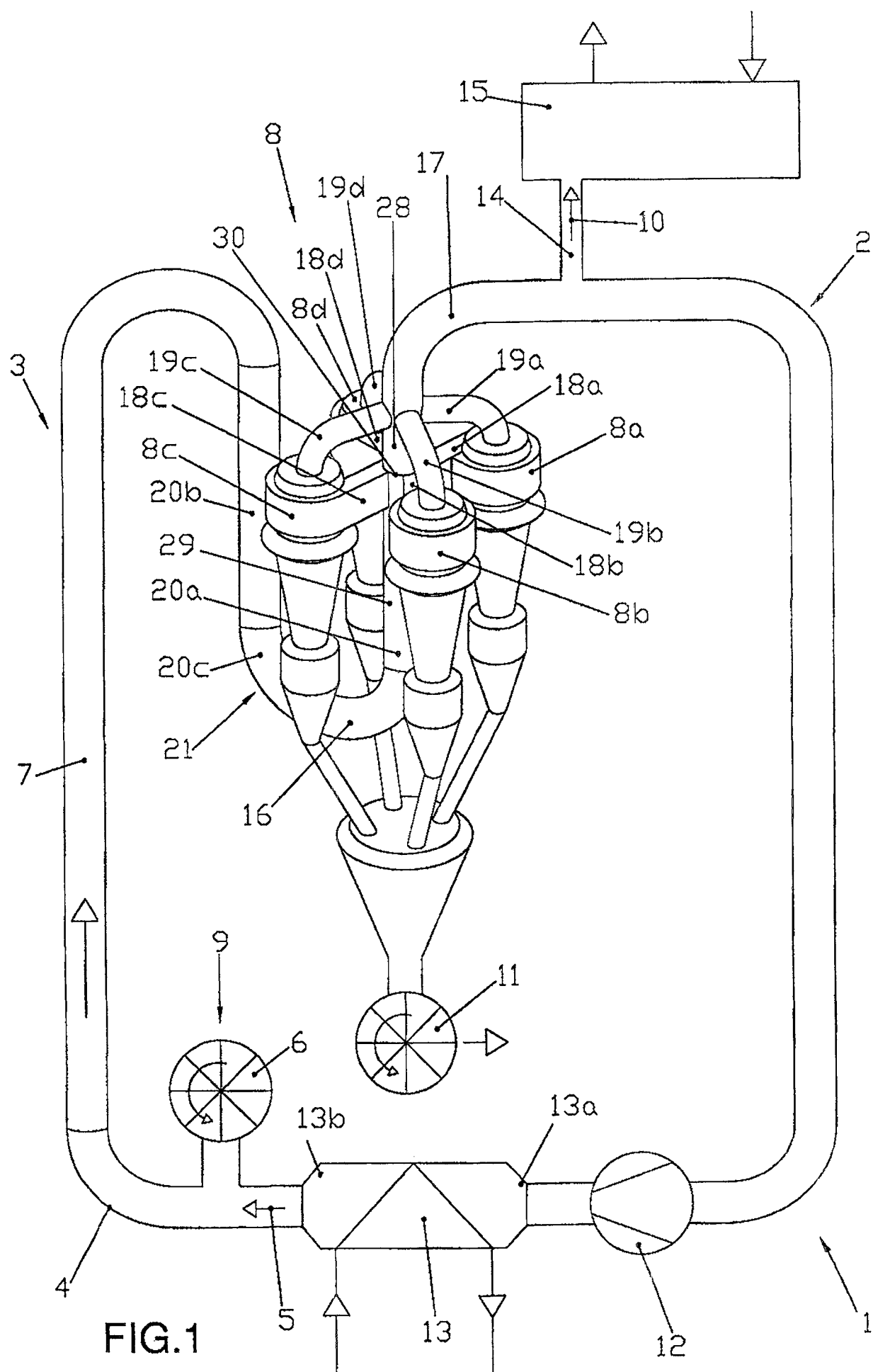


FIG.1

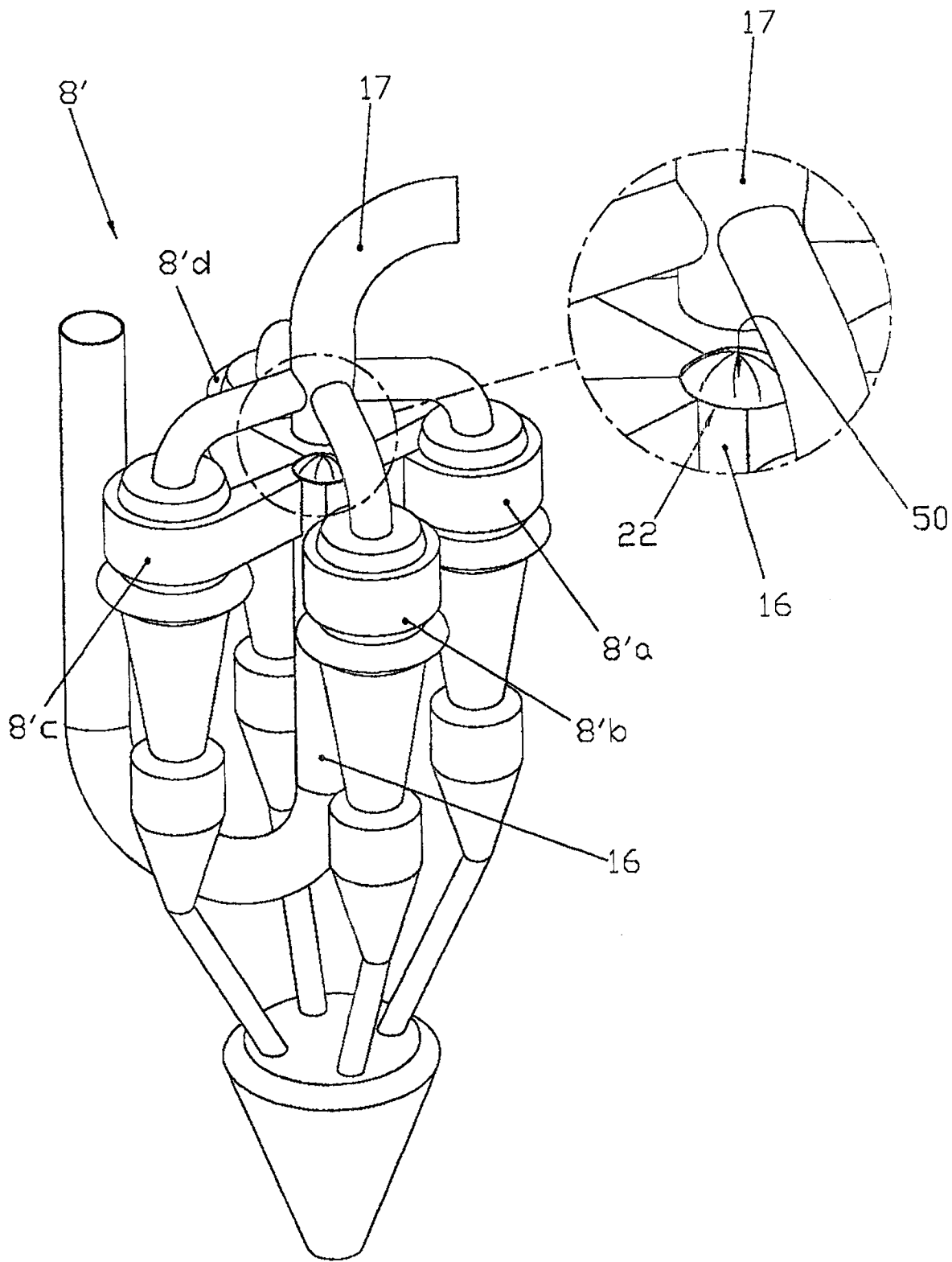


FIG.2

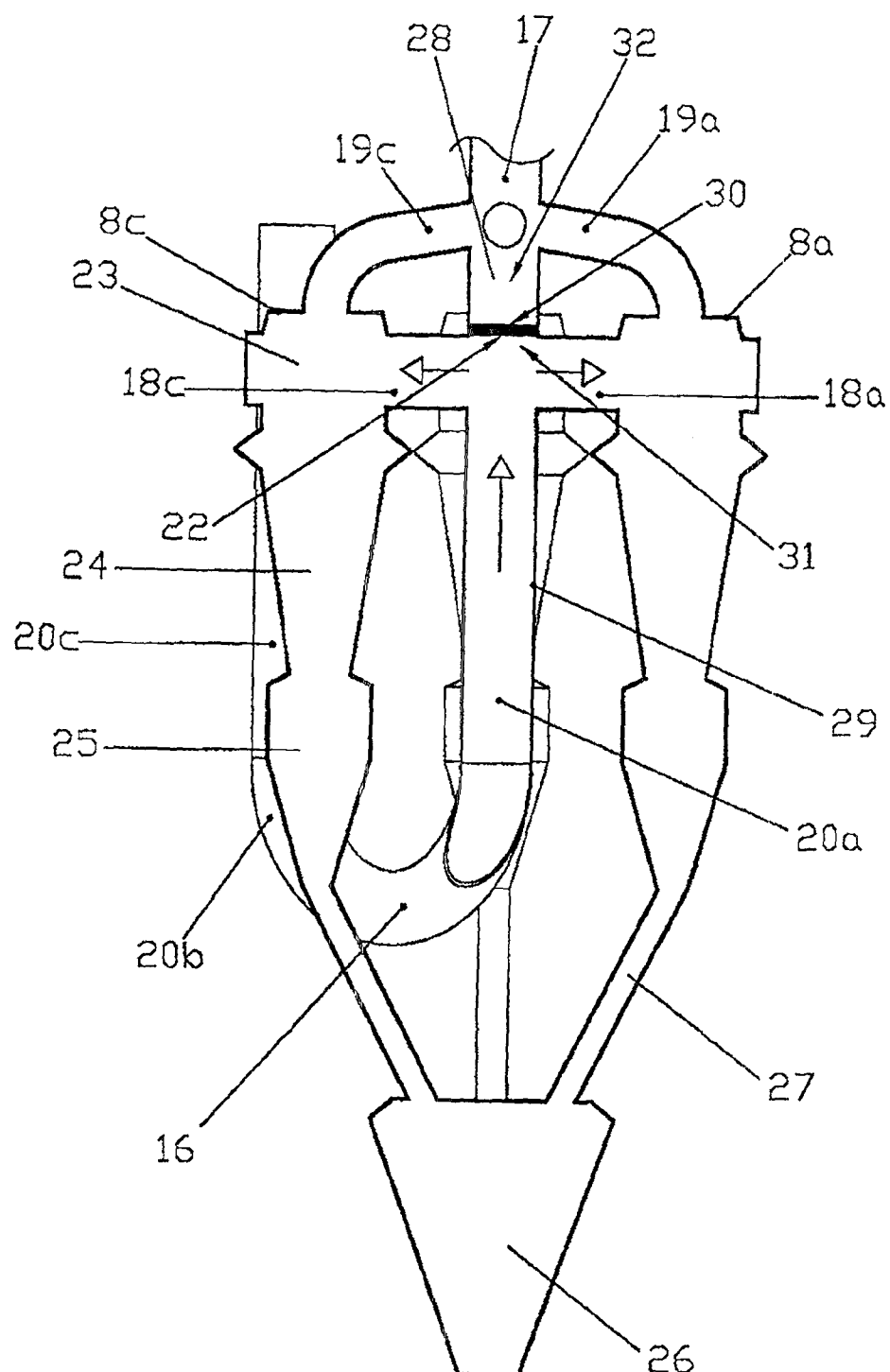
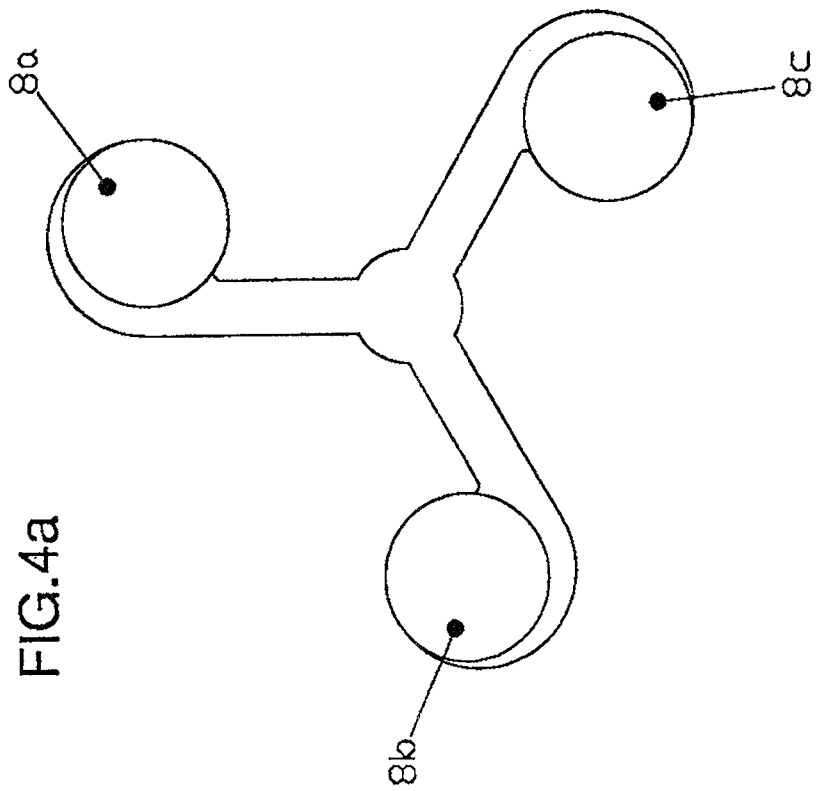
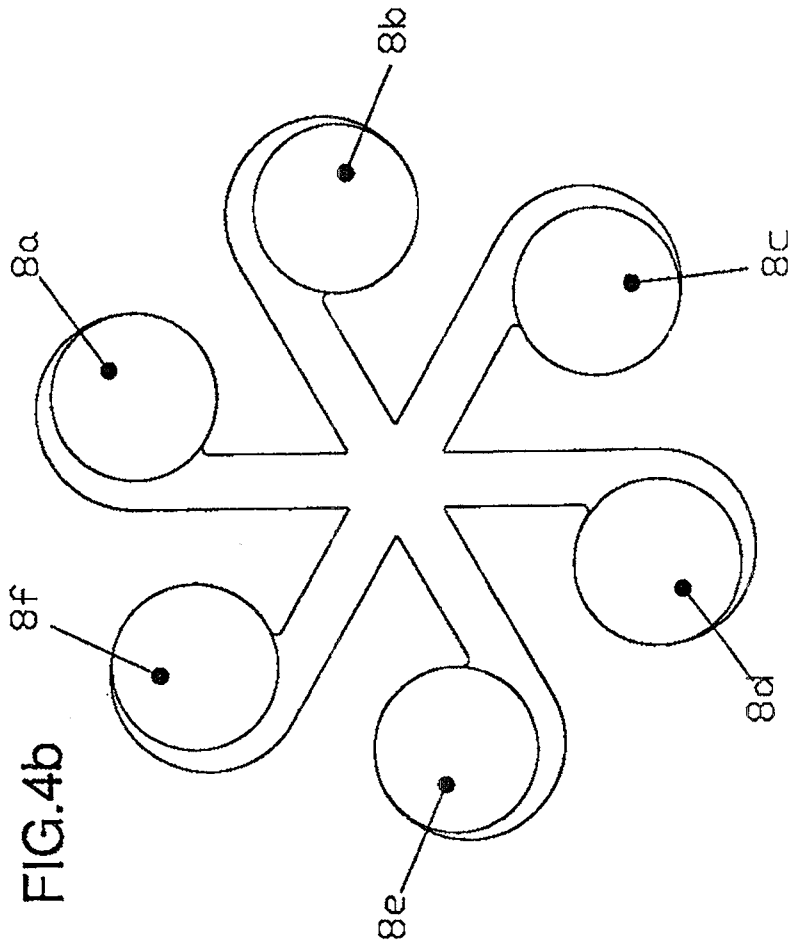
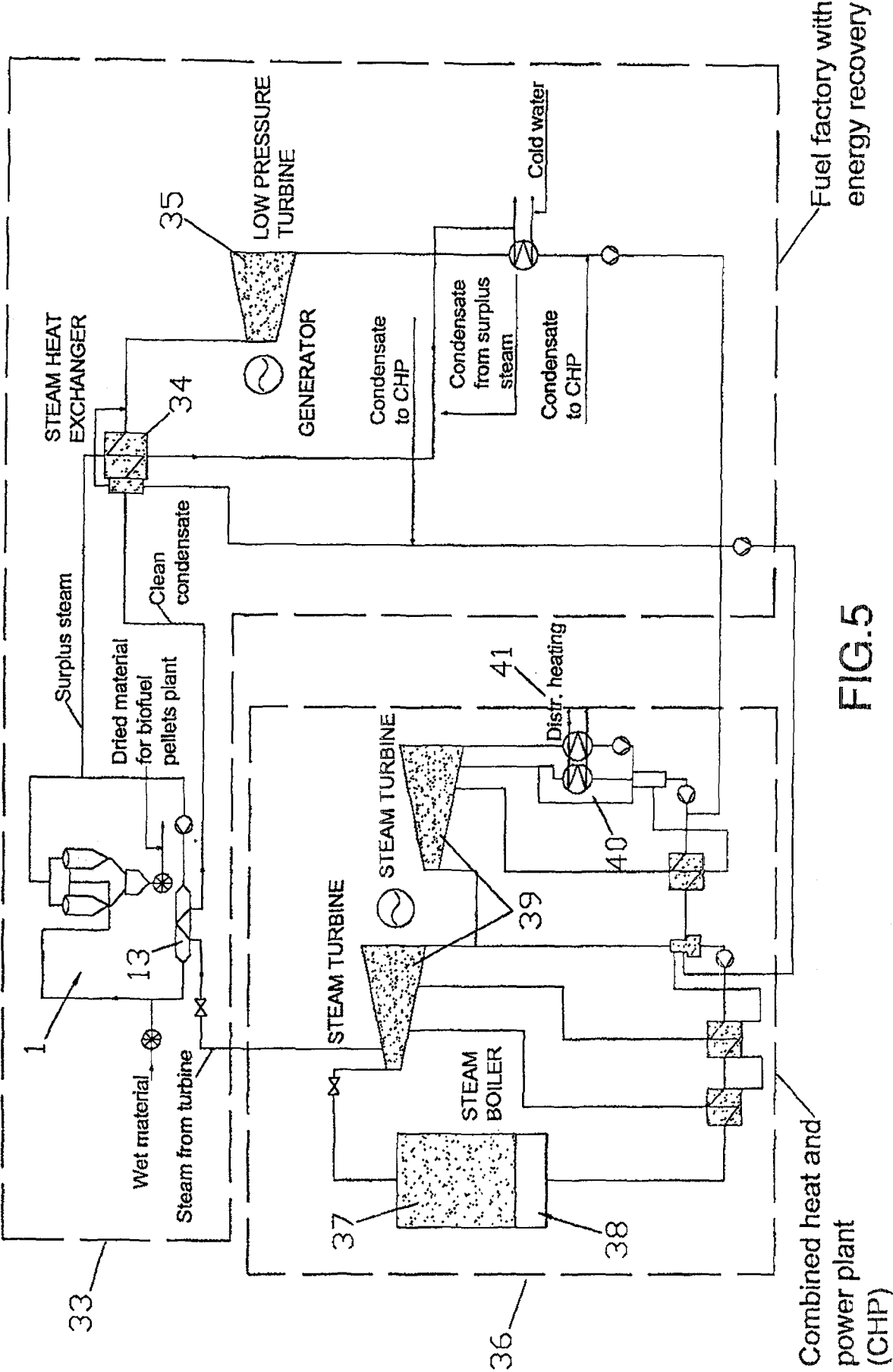


FIG.3





INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2010/050975

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: F26B, B04C, B01J, B01D

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2074299 A (SALEM CORPORATION), 28 October 1981 (28.10.1981), page 1, line 125 - page 2, line 24, figure 2, abstract --	1-2,10,13-14
Y	Borde, I., Levy, A. "Pneumatic and Flash Drying In: Handbook of Industrial Drying [online] CRC Press 2007 [retrieved on 2010-12-13] Retrieved from the Internet: < http://www.crcnetbase.com/doi/pdf/10.1201/9781420017618.ch16 >, figure 16.1; paragraphs 16.2,16.3,16.4 --	3-9,11,15-19
A	GB 1494487 A (HOECHST AKTIENGESSELLSCHAFT), 7 December 1977 (07.12.1977), page 3, line 2 - line 35, figure 3, abstract --	3-9,11,15-19

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

20 December 2010

Date of mailing of the international search report

23-12-2010

Name and mailing address of the ISA/

Swedish Patent Office

Box 5055, S-102 42 STOCKHOLM

Facsimile No. +46 8 666 02 86

Authorized officer

Charlott Galant / JA A

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INTERNATIONAL SEARCH REPORT

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 2559944 Y SHI WENWEI, 2003-07-09; (abstract) Retrieved from: EPODOC database; Original document: Figure 1 --	3-9,11,15-19
Y	Schmidt, E. "Dust Separation". In Ullman's Encyclopedia of Industrial Chemistry [online] Wiley Online Library, 15 Jan 2008 [retrieved on 2010-12-13] Retrieved from the Internet: < http://onlinelibrary.wiley.com/doi/10.1002/14356007.b02_13.pub2/full >, paragraph 3.4 --	3-9,11,15-19
Y	"Dust collector" In: Wikipedia [online] Wikipedia 2 sept 2009, [retrieved on 2010-12-13] Retrieved from Internet: < http://en.wikipedia.org/w/index.php?title=Dust_collector&oldid=311375655 >, page 3, paragraph "Multiple-cyclone separators" --	3-9,11,15-19
A	US 3720253 A (M. BALLAS ET AL), 13 March 1973 (13.03.1973), figure 1, abstract --	3-9,11,15-19
A	US 5907910 A (HEUMANN), 1 June 1999 (01.06.1999), column 1, line 31 - line 50, abstract --	3-9,11,15-19
A	US 6858130 B2 (HILTUNEN), 22 February 2005 (22.02.2005), column 2, line 35 - line 40, figures 2-3, abstract --	3-9,11,15-19
A	EP 119387 A1 (SUZHOU CLEAN BLOOM ELECTRIC CO. LTD.), 18 November 2009 (18.11.2009), abstract -- -----	3-9,11,15-19

International patent classification (IPC)**F26B 3/06** (2006.01)**B04C 5/28** (2006.01)**B01D 45/12** (2006.01)**Download your patent documents at www.prv.se**

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2010/050975

GB	2074299	A	28/10/1981	DE	3039159 A	24/09/1981
				FR	2478287 A	18/09/1981
GB	1494487	A	07/12/1977	AU	7600174 A	03/06/1976
				BE	822953 A	04/06/1975
				CH	593869 A	15/12/1977
				DE	2360235 A	23/10/1975
				FR	2252989 A,B	05/05/1978
				IT	1026724 B	20/10/1978
				JP	50086749 A	12/07/1975
				NL	7415599 A	06/06/1975
US	3720253	A	13/03/1973	DE	2162536 A	19/10/1972
				DK	135330 B,C	19/09/1977
				GB	1338033 A	21/11/1973
				IL	38200 A	10/02/1975
				NL	7204121 A	04/10/1972
US	5907910	A	01/06/1999	NONE		
US	6858130	B2	22/02/2005	AT	374646 T	15/10/2007
				AU	770337 B	19/02/2004
				AU	3382301 A	20/08/2001
				CA	2399422 A	16/08/2001
				CN	1227052 C	16/11/2005
				CN	1422172 A	04/06/2003
				DE	60130740 D,T	17/07/2008
				EA	003446 B	26/06/2003
				EP	1261408 A,B	03/10/2007
				FI	111229 B	30/06/2003
				FI	20000262 A	09/08/2001
				JP	2003522013 T	22/07/2003
				SE	521088 C	30/09/2003
				SE	0200737 A,L	09/08/2003
				US	20020033098 A	21/03/2002
				WO	0158568 A	16/08/2001
EP	119387	A1	18/11/2009	NONE		