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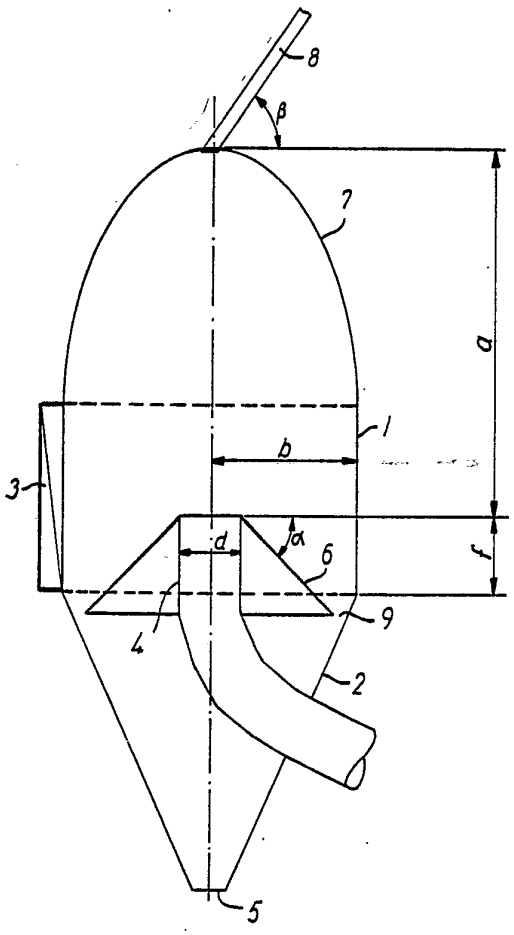
Published
With international search report.
With amended claims and statement.

(54) Title: HEAT EXCHANGER

(57) Abstract

A heat exchanger in the form of a vessel for heat exchange of a pulverulent solid material and a gas, e.g. for preheating raw materials prior to a burning process by use of the hot exit gases fed to the vessel consists of a hollow cylindrical central part (1) with a tangential gas inlet (3), a conical base (2) with a material outlet (5), and a downwardly orientated gas outlet (4), a concave upper part (7, 7') facing the central part and with at least one material inlet (8); the downwardly orientated gas outlet (4) is mounted initially axially as a central pipe inside the vessel and is provided with a skirt (6); the height of the upper part, the distance of the material inlet from the vertical axis of the heat exchanger and the inclination of the inlet to the horizontal plane, the height of the central pipe gas inlet (4) above the lower end level of the central part (1) of the vessel and the inclination of the skirt (6) are all dimensioned so as to provide optimum conditions, partly for heat exchange in radial countercurrent between material and gas, partly for separation of material from gas inside the vessel due to the downwardly orientated axial and tangential gas velocities.



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Heat exchanger.

The present invention relates to a heat exchanger of the type used for obtaining heat exchange of a pulverulent solid material and a gas. Such heat exchangers are used e.g. for preheating mineral raw material which is subsequently subjected to a burning process; the preheating being effected by use of the hot exit gases from the burning process.

Preheating of the pulverulent solid material may be carried out in a cyclone system consisting of several cylindric cyclones having a vertical or horizontal main axis and a conical bottom ending in an outlet for the solid material as it is known from e.g. chapter 20 of Duda: Cement-Data-Book, volume 1, ed. 3 (1985), Bauverlag GmBH, Wiesbaden und Berlin.

Prior art cyclones having a vertical axis are generally delimited at the top by a circular top plate or a circular opening in a downwards concave cyclone top part. A gas outlet pipe or a "central pipe" may extend through the plate or opening down into the cyclone cylinder. Solid material suspended in gas is supplied tangentially via a suspension inlet into the cylinder. Owing to the circulating movement of the gas therein the solid material is flung towards the vessel wall by the centrifugal force where it is stopped og subsequently slides down the wall onto the conical bottom and out through the material outlet while the gas leaves the vessel through the central pipe. Such heat exchange cyclones are disclosed in i.a. patents Nos. DE 1,913,305; SE 221,971; 4,245,981, and DE 1,286,696. Heat exchange in cyclones of this type is effected as a co-current heat exchange in that the material during the heat exchange is circulated together with the gas flow in the cyclone. In order for the material to obtain the temperature desired for preheating prior to a burning process it is generally necessary to employ a plurality of such co-current heat exchangers in series, typically four or five stages for preheating of e.g. cement raw material, thus causing this part of a kiln plant to have a considerable height of construction demanding an equally considerable consumption of construction materials.

In case of counter-current heat exchange, as it is known from i.a. GB-A-988,284 or from DK patent application No. 1600/85, the centripetal travelling direction of the tangentially introduced gas is used counter to the centrifugal travelling direction of the material introduced close to the cyclone axis in order to obtain an increased heat exchange effect as compared to conventional cyclones having a vertical axis, and the use of horizontal counter-current cyclones in preheaters may contribute to delimit the construction height of the preheater. Horizontal cyclones, however, suffer from the drawback that, typically, their separation rates are smaller than those of conventional cyclones.

Therefore, it is an object of the present invention to provide a heat exchanger having a vertical main axis and operating according to the counter-current principle and which heat exchanger is sufficiently efficient as to heat exchange as well as to material separation to replace at least two of the hitherto used stages of a cyclone preheater.

According to the invention this object is achieved by a heat exchanger comprising a cylindrical central part having a downward tapering conical base, a concave upper part facing the central part and constituting the upper delimitation of the heat exchanger, a tangential gas inlet in the wall of the cylindric part, and an at least initially axially mounted gas outlet or central pipe said inlet and outlet contributing jointly to form a spiral gas flow inside the vessel, at least one material inlet mounted in the upper part, and a material outlet at the lower part of the base; the material inlet and outlet being placed so as to impart to the pulverulent solid material introduced into the heat exchanger a centrifugal momentum thereby conveying the material, while heat exchanging with the gas, through the heat exchanger counter-currently to the gas which moves centripetally towards the gas outlet pipe; and which heat exchanger is characterized in that the axially mounted gas outlet is a downwardly orientated pipe which extends from its at least initially central position inside the vessel down through the conical base; in that the radius b of the central part is comprised within the range $1,5 \leq b \leq 3,0d$, where d is the diameter of the gas outlet pipe; and in that the distance a between the upper end of the gas outlet pipe and

the top of the upper part of the heat exchanger is within the range $2d \leq a \leq 5d$.

The design of the upper heat exchanger part with the above-specified dimensions means partly that the axis of the heat exchanger becomes longer thus entailing lower radial gas velocities inside the vessel towards the gas outlet pipe and hence decreasing the entrainment of the treated material which increases the separation rate of the heat exchanger, partly that, compared to prior art heat exchanger constructions, an improved axial material flow is obtained due to the resulting force exerted on the particles, and which is composed of centrifugal and gravititional forces, carrying the particles counter-currently to the gas flow in radial as well as axial direction.

The gas outlet pipe of the heat exchanger is downwardly orientated in order to ensure optimum interaction between the axial and tangential gas velocities and extends therefore out through the conical base. Owing to the downward axial velocity which may be generated in the heat exchanger the material is sucked into and distributed in the heat exchanger and due to the tangential velocity the material is flung towards the wall of the vessel where it encounters the hottest gas and it is separated from the gas. These two effects are adapted to each other by adjustment of the distance between the upper end of the gas outlet pipe and the top of the upper part of the heat exchanger proper.

The heat exchanger is provided with at least one material inlet in the top of the concave upper part at a distance in the horizontal plane from the cyclone axis of up to 1.5 times the diameter of the gas outlet pipe and has an inclination to the horizontal plane of less than 90° in the gas flow direction. This flow forms a radial centrally orientated potential vortex from the gas inlet to the central pipe and therefore, the material is introduced close to the centre of said vortex thus causing in radial direction a counter-current movement of material and gas to the material particles, with a far higher density than the gas, being flung towards the vessel wall by the centrifugal force.

The gas outlet pipe or central pipe of the heat exchanger is mounted

so that the upper inlet end of the pipe inside the heat exchanger is placed at a distance of from 0 to 2.0 times the internal diameter of the central pipe above the lower end level of the cylindrical central part. Close to the inlet opening itself the pipe may be provided with a skirt of a heat resistant material and inclining from the pipe in order to increase the heat exchange. The skirt may form an angle of from 40° to 70° with the horizontal plane and extend towards the inner wall of the conical base so as to form an annular slit between said wall and the circumference of the skirt through which slit the separated material may pass towards a material outlet. The skirt provides more symmetrical conditions for the gas and material movements inside the heat exchange chamber, the disturbing effects upon the movement at the outlet of the central pipe through the conical part being eliminated and the skirt at the same time contributing to forcing the material towards the inner wall of the vessel into the area with the highest gas temperature.

According to a further embodiment of the heat exchanger a shortened conical base, the underside of the skirt, and the gas outlet pipe constitute together the lower delimitation of the vessel thus ensuring that a substantial reduction of the height of the heat exchanger is achieved. In that case the annular slit between the skirt and the conical base part conveys the separated material to an aerated trough conveyer for hot material.

The invention is explained in more detail in the following with reference to the accompanying drawings, which are diagrammatical and illustrate non-limiting examples of embodiments and in which

Figure 1 shows a vertical axial elevation of a heat exchanger having a conical base,

Figure 2 is a vertical axial elevation of a heat exchanger having an upper part design different from the one shown in Figure 1,

Figure 3 is the heat exchanger shown Figure 1 seen from above, and

Figure 4 shows a heat exchanger having a shortened conical base.

The heat exchanger shown in Figures 1 and 2 consists of a vessel having a hollow cylindrical central part 1 with a vertical axis, a downward tapering conical base 2 having a material outlet 5, a gas inlet 3 in the wall of the central part 1 for tangential feeding of the gas into the vessel, and an upper part shaped as a concave cover 7 or 7′ facing the central part. The heat exchanger shown in Figure 1 has an ellipsoidal upper part while the one shown in Figure 2 has a frusto-conical shaped upper part. Inside the vessel is mounted an axial gas outlet pipe or central pipe 4, which extends downwardly out through the side wall of the conical base 2. The radius b of the vessel is within the range $1,5 \leq b \leq 3,0d$, where d is the internal diameter of the gas outlet pipe inside the vessel. The distance a from the upper end of the gas outlet pipe 4 inside the central part 1 to the top of the upper part of the heat exchanger proper is within the range $2d \leq a \leq 5d$.

At its top the upper part has a material inlet 8. The inlet opening itself is placed at a distance g within the range $0 < g \leq 1,5d$ in the horizontal plane from the vertical axis of the vessel. The inlet is designed as a circular pipe which does not extend into the vessel and which forms an angle β of less than 90° with the horizontal plane the inclination having the same direction as the travelling direction of the spiral gas flow inside the vessel. The distance g and the inclination β contribute to the establishment of the optimum countercurrent movement in radial direction between material and gas inside the vessel. Only one of several possible material inlets at the top of the upper part is shown in the figures.

In Figure 3 a dash-dotted arrow line indicates the movement of the tangentially introduced gas flow through the gas inlet 3 towards the axially positioned gas outlet 4 inside the central part 1 of the vessel and a dotted arrow line indicates the centrifugal movement of the added material from the material inlet 8 towards the vessel wall.

In order to create optimum gas flow velocities for the heat exchange the gas outlet or the central pipe 4 extends downwards out through the conical base 2. Also in order to ensure optimum movement conditions for gas and material inside the vessel the central pipe within

the vessel is provided with a skirt 6 close to the gas inlet proper of the pipe which skirt forms an angle α within the range $40° \leq \alpha \leq 70°$ in relation to the horizontal and extends towards the inner wall of the conical base 2 so as to form jointly an annular slit 9 through which separated material may pass downwards to the material outlet 5. The annular slit may for instance have a width of 150 mm. When using a skirt the inlet proper of the central pipe 4 inside the vessel conveniently has a height f comprised within the range $0 \leq f \leq 2{,}0d$ above the lower end level of the central part of the cylindrical vessel.

The alternative embodiment for the heat exchanger according to the present invention shown in Figure 4 and with a frusto-conical upper part 7', a material inlet 8 and a gas inlet 3, is characterized in having a considerably shortened conical base 2 so that said shortened base, the underside of the skirt 6 and the central pipe 4 constitute the lower delimitation of the heat exchanger. In this embodiment separated material pass from the annular slit 9 to a not-shown aerated trough conveyer for transportation of hot material to a subsequent treatment stage of the plant.

Claims

1. A heat exchanger in the form of a vessel having a cylindric central part (1), a downward tapering conical base (2), a concave downwards orientated upper part (7) facing the central part and constituting the upper delimitation of the heat exchanger, a tangential gas inlet (3) in the wall of the cylindric central part and an at least initially axially mounted gas outlet (4) contributing to form a spiral gas flow inside the vessel, at least one material inlet (8) mounted in the upper part of the vessel, and a material outlet (5) at the lower part of the vessel; the material inlet and outlet being placed so as to impart to the pulverulent solid material introduced into the heat exchanger a centrifugal momentum thus conveying the material, while heat exchanging with gas, through the heat exchanger counter-currently to the gas which moves centripetally towards the gas outlet pipe, characterized in that the axially mounted gas outlet is a downwardly orientated pipe (4) which extends from its at least initially axial central position inside the vessel down through the conical base (2) of same; in that the radius b of the central part (1) is within the range $1,5 \leq b \leq 3,0d$, where d is the diameter of the gas outlet pipe (4); and in that the distance a from the upper end of the gas outlet pipe (4) to the top of the upper part (7) of the heat exchanger is within the range $2d \leq a \leq 5d$.

2. A heat exchanger according to claim 1, characterized in that the material inlet (8) at the top of the upper part (7) is inclined in the same direction as the travelling direction for the spiral gas flow inside the vessel; and in that its inclination β to the horizontal plane is less than 90°; and in that the material inlet proper in the horizontal plane is at the distance g within the range $0 \leq g \leq 1,5d$ from the vertical axis of the heat exchanger.

3. A heat exchanger according to claim 1 or 2, characterized in that the upper end of the gas outlet pipe (4) inside the cylindrical central part (1) is at a distance f within the range $0 \leq f \leq 2,0d$ from the lower end level of the cylindrical central part and which close to said upper end is provided with a heat resistant

skirt (6) inclining at an angle α of between 40° and 70° with the horizontal plane and which skirt extends towards the inner wall of the conical base (2) so as to form an annular slit (9) between said base and the circumference of the skirt.

4. A heat exchanger according to any one of the preceding claims, characterized in that the conical base (2) of the chamber is shortened; and in that the shortened conical base and the underside of the skirt (6) forming together the annular slit (9) jointly with the pipe (4) constitute the lower delimitation of the vessel.

AMENDED CLAIMS
[received by the International Bureau
on 3 August 1989 (03.08.89)
original claims 1-4 replaced by amended claims 1-3 (2 pages)]

1. A heat exchanger in the form of a vessel having a cylindric central part (1), a downward tapering conical base (2), a concave downwards orientated upper part (7) facing the central part and constituting the upper delimitation of the heat exchanger, a tangential gas inlet (3) in the wall of the cylindric central part and an at least initially axially mounted, downwardly orientated gas outlet (4) contributing to form a spiral gas flow inside the vessel, at least one material inlet (8) mounted in the upper part of the vessel, and a material outlet (5) at the lower part of the vessel; the material inlet and outlet being placed so as to impart to the pulverulent solid material introduced into the heat exchanger a centrifugal momentum thus conveying the material, while heat exchanging with gas, through the heat exchanger counter-currently to the gas which moves in a substantially horizontal direction centripetally from the gas inlet (3) towards the gas outlet pipe (4); c h a r a c t e r i z e d in that the radius b of the central part (1) of the vessel is within the range $1,5 \leq b \leq 3,0d$, where d is the diameter of the gas outlet pipe (4); and in that the distance a from the upper end of the gas outlet pipe (4) to the top of the upper part (7) of the heat exchanger is within the range $2d \leq a \leq 5d$; and in that the upper end of the downwardly orientated gas outlet pipe (4) extending from its at least initially axial central position inside the vessel down through the conical base (2) of same is at a distance f within the range $0 \leq f \leq 2,0d$ inside the cylindrical central vessel part (1) from the lower end level of said part; and which gas outlet pipe (4) close to its upper end is provided with a heat resistant skirt (6) inclining at an angle α of between 40° and 70° with the horizontal plane.

2. A heat exchanger according to claim 1, c h a r a c t e r - i z e d in that the opening of the material inlet (8) at the top of the upper part (7) join into the wall proper of this part and in that the inlet duct is inclined in the same direction as the travelling direction for the spiral gas flow inside the vessel; and in that its inclination β to the horizontal plane is less than 90°;

and in that the material inlet proper in the horizontal plane is at the distance g within the range $0 \leq g \leq 1,5d$ from the vertical axis of the heat exchanger.

3. A heat exchanger according to any one of the preceding claims, c h a r a c t e r i z e d in that the conical base (2) of the chamber is shortened; and in that the shortened conical base and the underside of the skirt (6) forming together an annular slit (9) jointly with the pipe (4) constitute the lower delimitation of the vessel.

STATEMENT UNDER ARTICLE 19

In the amended claim 1 the invention has been characterized on the background of the hitherto known technique as described in the opening part of the original application description with the addition of DE 1913305, FR 736458 and US 3740865 as now cited in the International Search Report of 1989-06-26 which are together considered the most pertinent prior art references. Consequently the hitherto characterizing feature of the axially mounted gas outlet (4) being "downwardly oriented" has been moved to the preamble of the claim in the mention of said gas outlet while the wording of the characterizing part of the claim has been amended to also include the features of hitherto claim 3 and with the insertion of the wording "[the gas outlet pipe (4)] extending from its initially axial central position inside the vessel down through the conical base of same ..." as a feature known per se from separator constructions but in the present invention contributing to a new and surprising heat exchanger effect. Thereby the characterizing clause of claim 1 has been limited substantially to the new geometry proper of heat exchanger starting with "characterized in that the radius be of the central part (1) of the vessel is ...". Further in adding the wordings "in a substantially horizontal direction" and "from the gas inlet (3)" to the mention in the preamble of claim 1 of how the gas moves from the tangential gas inlet centripetally to the gas outlet pipe within the heat exchanger vessel the counter-current movement of the material in relation to the gas has been stressed and thus further distinguish the heat exchanger according to the invention from especially the separators according to the citations.

In claim 2 the wording below in []-brackets have been added to the characterizing part of the claim to underline the nature of the material inlet of the heat exchanger, said material inlet hereby distinguishing clearly from inlets according to the Y-citations of the International Search Report:

"... characterized in that [the opening of] the material inlet (8) at the top of the upper part (7) [join into the wall proper of this part and that

the duct] is inclined ..." the above citations either disclosing heat exchangers with gas exhaust pipes the lowermost ends of which penetrates a certain distance into the heat exchanger entailing the drawbacks of reducing the effective heat exchange volume within the vessel and demanding constructional steps to heat protect the lowermost pipe ends and having either an annular material inlet or a material inlet in the riser pipe proper (DE 1913305 and DE 1508570) or disclose a separator with no separate material inlet (FR 736458) or disclose a combined dryer-pulverizer/separator also with no separate material inlet (US 3740865).

The original claim 3 has been deleted and its characterizing clause included in new claim 1 with the exception of the three last lines of the claim starting by "... and which skirt extends" has been deleted in view of the citation FR 736458.

In original claim 4 renumbered as new claim 3 the mention of the "annular slit (9)" has been editorally altered according to the above deletion.

In the description mention of the Y-citations should be made in the first paragraph of page 2 in addition to the already referred technique in this paragraph and in paragraph 3 of the same page amendments should be made to make the wording of this paragraph correspond to the suggested new claim 1.

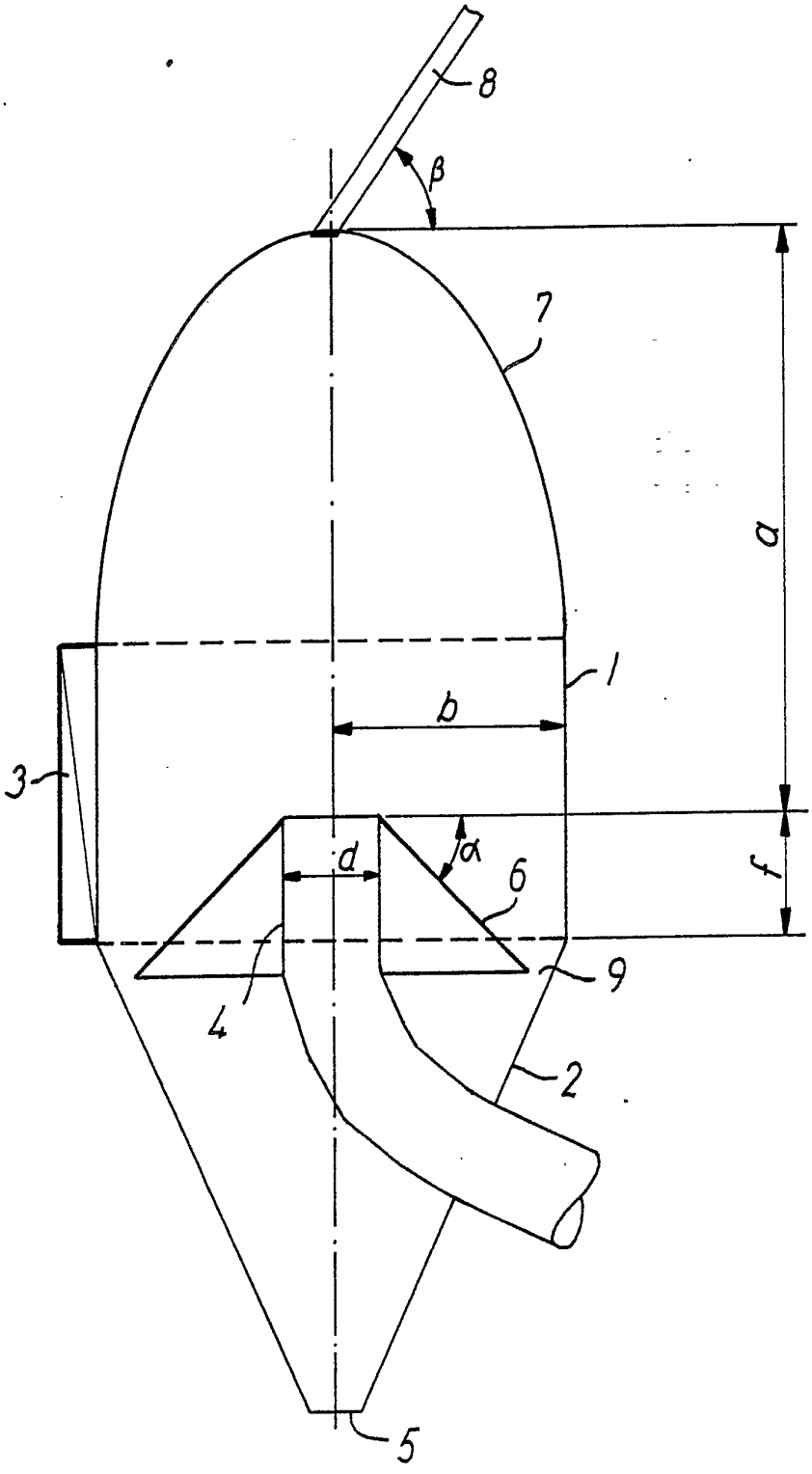

FIG.1

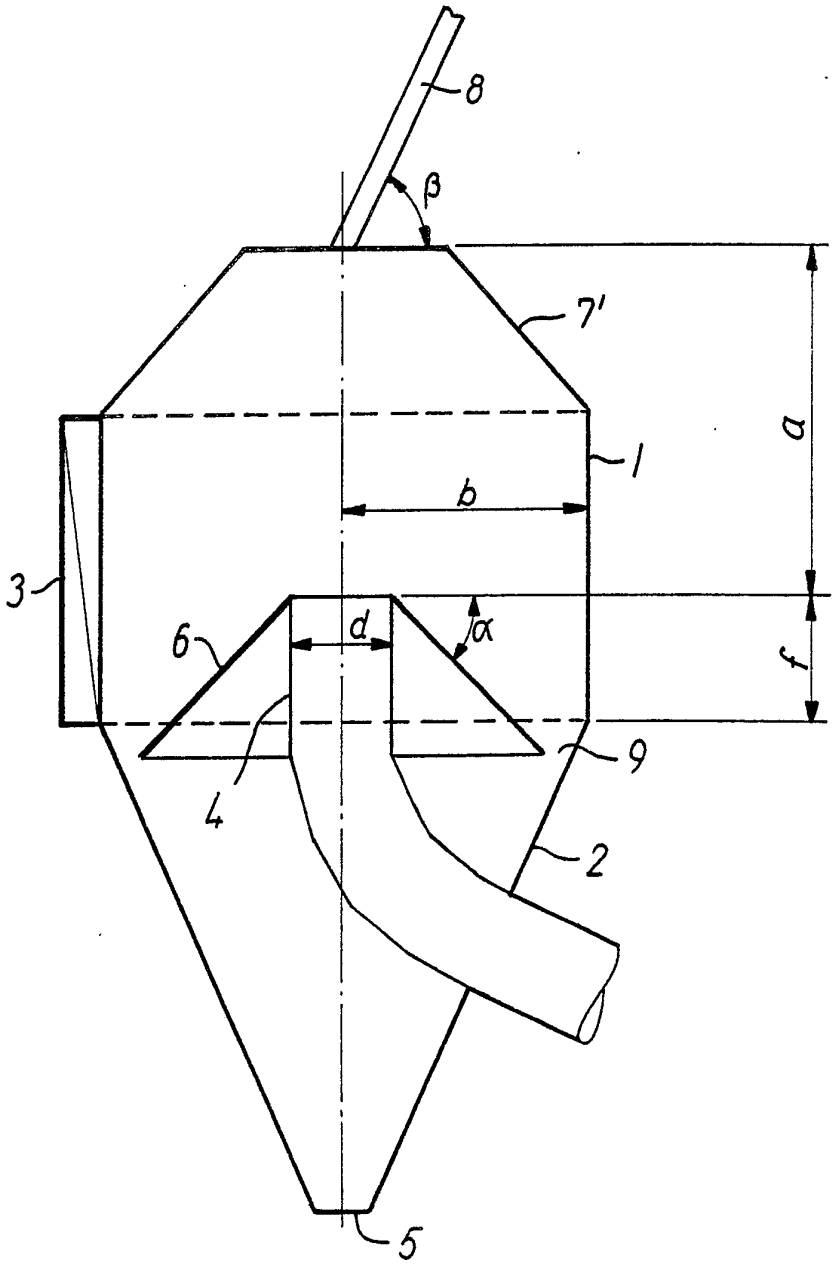

FIG. 2

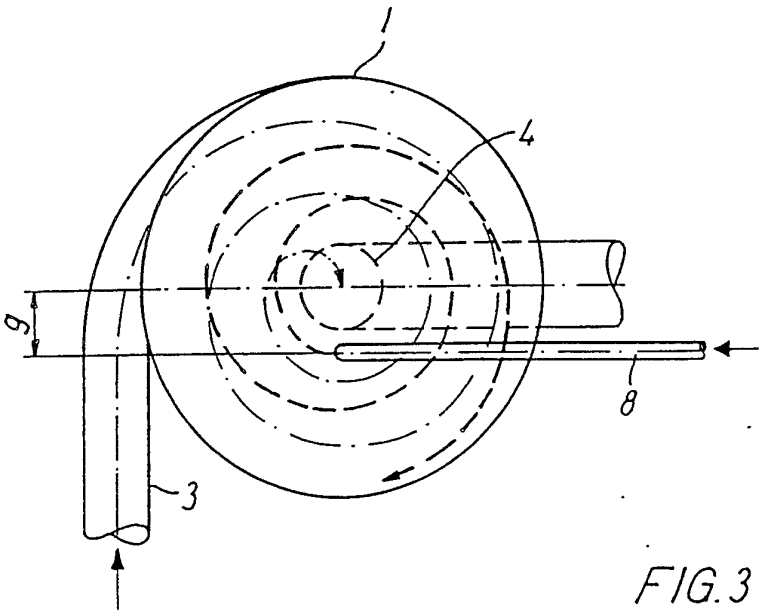

FIG. 3

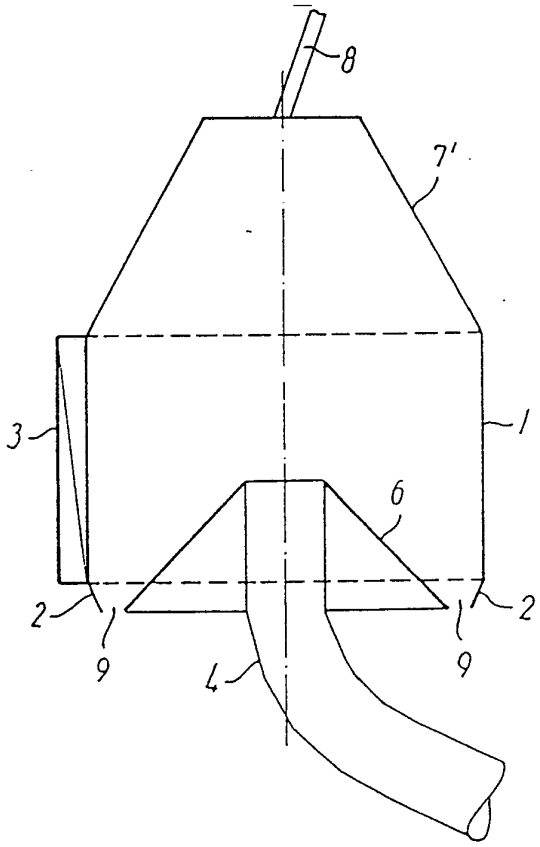

FIG. 4

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK89/00024

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

F 28 C 3/12, F 27 D 13/00, B 04 C 5/00

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 4	F 28 C 3/00, /10-/14; F 28 F 13/06, /08, /12; F 26 B 3/10-/16, 17/00, /10; F 27 B 7/34; F 27 D 13/00; B 01 D 45/12; B 04 C 1/00, 3/00, /02, /06, 5/00, /14, /181, /20, 9/00 .../...

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	DE, A, 1 913 305 (BOIE) 24 September 1970	1-4
Y	DE, A, 1 508 576 (KLÖCKNER-HUMBOLDT-DEUTZ AG) 30 October 1969 & BE, 697001	1, 2
Y	FR, A, 3 736 458 (M. EILLIAM ALEXANDER) 24 November 1932	1, 2, 3
Y	US, A, 3 740 865 (LAGUILHARRE) 26 June 1973 & NL, 7100849 FR, 2080016 DE, 2103332 CH, 531693 GB, 1304793	1, 3, 4
A	SE, A, 221 971 (WESTFALIA DINNENDAHL GRÖPPEL AG) 6 August 1968	
A	DE, A, 1 286 696 (RHEINSTAHL ECO GMBH) 15 April 1971 .../...	

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1989-06-16	1989 -06- 16
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Annette Riedel

Form PCT/ISA/210 (second sheet) (January 1985)

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

II FIELDS SEARCHED (CONT.)

US Cl 34:10, 57, 57E, R, 58, 79
55:80, 83, 396, 428, 448, 529
432:14, 27, 58, 80, 106
Nat. Cl 17e 8, 12e 3/05, 50e 3/10

V. ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE [1]

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers....., because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim numbers....., because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim numbers....., because they are dependent claims and are not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING [2]

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

☐ The additional search fees were accompanied by applicant's protest.

☐ No protest accompanied the payment of additional search fees.

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	DE, A, 1 442 732 (ISLER) 25 September 1969	
A	DE, A, 1 558 569 (KLÖCKNER-HUMBOLDT-DEUTZ AG) 2 April 1970	
A	GB, A, 300 841 (WILLIAM ALEXANDER) 22 November 1928	
A	GB, A, 910 434 (ACCESSORIES COMPANY LIMITED) 14 November 1962	
A	Patent Abstract of Japan, Vol 9, No 331, (C-321), abstract of JP 60-161762, publ 1985-08-23	
A	US, A, 2 044 614 (JOSEPH H. KEENAN) 16 January 1936	
A	US, A, 4 245 981 (TEGTMEIER ET AL) 20 January 1981	