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

(11) EP 0 779 109 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
18.06.1997 Bulletin 1997/25

(51) Int Cl.[6]: **B07B 4/08**, B07B 9/00

(21) Application number: **96630074.1**

(22) Date of filing: **06.12.1996**

(84) Designated Contracting States:
DE FR GB IT SE

(30) Priority: **13.12.1995 US 571800**

(71) Applicant: **BELOIT TECHNOLOGIES, INC.**
Wilmington, Delaware 19803 (US)

(72) Inventor: **Bielagus, Joseph B.**
Tualatin, Oregon 97062 (US)

(74) Representative: **Schmitz, Jean-Marie et al**
Dennemeyer & Associates S.A.,
P.O. Box 1502
1015 Luxembourg (LU)

(54) Low velocity air density separator

(57) A fan (30) draws air out of a cyclone (28) and through an open-bottomed separation chamber (22) at approximately seven hundred to eight hundred feet per minute. Shredded plastic bottles or other mixed particulate material is metered into the separation chamber and is evenly distributed by a grid (36) of closely spaced narrow bars (38) which extends into the separation chamber. The bars are cantilevered into the separation chamber and are caused to vibrate by an oscillatory mounting. The shredded material may be fed by an ordinary chute (60) without an air lock onto the deck of the grid of bars. Air moving rapidly between the bars lifts and separates the various constituents of the shredded bottles. The denser particles fall down through the bars and are recovered as the heavy recyclable fraction. The lightweight particles including paper are drawn up through the separation chamber and into the cyclone. Dense material such as trash or other inadvertently added substances which are too large to pass through the bars is oscillated along the inclined bars to an exit chute.

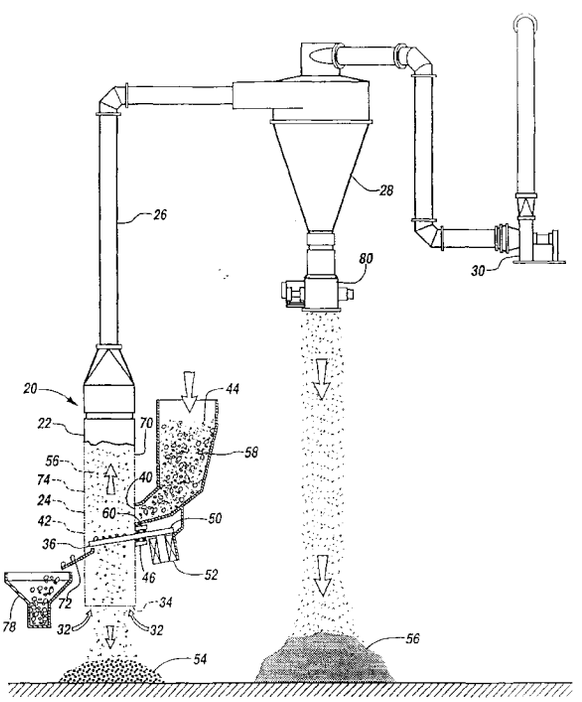

Fig.1

EP 0 779 109 A1

Description

FIELD OF THE INVENTION

The present invention relates to apparatuses and methods for separating fractions of a particulate material in general. More particularly, the present invention relates to apparatuses and methods for utilizing air to separate components of a particulate material on the basis of differing attributes.

BACKGROUND OF THE INVENTION

The separation of a particulate material into various fractions on the basis of density is performed in many industrial processes. In the mining industry, heavy minerals are concentrated from ores for extraction. In agriculture, grain is separated from chaff and leaves are separated from stalks by the use of a current of air which lifts the lighter chaff or leaves away from the grain or stalks. In the wood pulping industry, a device known as an air density separator has been employed to separate wood chips of light colored wood from chips containing knots which are more dense.

The air density separator uses a vertical separation chamber through which a stream of air is drawn with a velocity in the range of four to five thousand feet per minute. Wood chips to be separated are metered by an auger into the separation chamber where the high velocity air stream disperses the chips evenly over the chamber. The more dense knots fall through the uprising current of air and are rejected. The lighter chips are drawn from the separation chamber by the flow of air and separated from the air by a cyclone.

Recent concern with waste reuse and progress in recycling post-consumer wastes have given rise to new and unique problems in the separation of materials. Voluntary, and in some cases mandatory, recycling has resulted in the collection and separation of a number of specific post-consumer packaging materials which have been identified as being constructed of a high volume material and thus likely candidates for economic recycling. Materials which have been so identified are the ubiquitous aluminum cans, glass bottles, plastic milk cartons and 1, 2 and 3 liter pop bottles.

The recycling of milk bottles and pop bottles has been identified as a candidate for economic recovery. However, the value of the recycled product is heavily dependent on its purity.

The recovery of high value materials from post-consumer wastes plays a critical role in reducing the landfill disposal of post-consumer wastes. High value products such as aluminum cans, newspapers, and plastic can reduce the cost of governmental subsidies and help finance the recovery of other materials from the waste stream. Further, the production of and marketing of the most valuable components of municipal waste creates a market and social climate for recycled products which is key to the economic recovery of a larger and larger fraction of consumer wastes. One major problem in recycling post-consumer plastic bottles is the removal of the labels, typically paper, from the plastic bottles.

What is needed is an apparatus and method for removing paper and thin gauge plastic from post-consumer plastic bottles.

SUMMARY OF THE INVENTION

The air density separation apparatus of the present invention employs a vertical air separation chamber. The vertical air separation chamber is connected to a cyclone which in turn is connected to a fan. The fan draws air out of the cyclone which in turn causes air to be drawn up through the open-bottomed separation chamber. In prior art air density separators utilized in separating wood chips from wood knots, air is drawn rapidly up through the separation chamber at four to five thousand feet per minute. The wood chips are metered into the separation chamber through an air lock or a supply auger. The auger dumps the chips into the high velocity air stream where the high velocity air disperses the chips across the separation chamber so that the rising stream of air may separate the chips based on their density and cross-sectional area.

With the low velocity air density separator of this invention, the separation chamber is somewhat longer and the air is drawn up through the chamber at approximately seven hundred to eight hundred feet per minute. Because of the relatively low velocity of the air, the air stream itself is noneffective at dispersing the shredded plastic bottles and their associated paper labels evenly into the air stream. In order to achieve the even distribution of the shredded bottles and the labels into the air stream, a grid of closely spaced narrow bars extends into the separation chamber. The bars are cantilevered into the separation chamber and are caused to vibrate by an oscillatory mounting. The shredded material may be fed by an ordinary chute without an air lock onto the deck of the grid of bars. Air moving rapidly between the bars lifts and separates the various constituents of the shredded bottles. The denser plastic walls of the bottle fall down through the bars and are recovered as the heavy recyclable fraction of the bottles. The lightweight paper is drawn up through the separation chamber and into the cyclone. The cyclone removes the lightweight paper from the air stream and air is drawn from the cyclone by a fan. In tests with material of a bulk density of 18.5 pounds per cubic foot, the air density separator of this invention is estimated to remove ninety-five to ninety-eight percent of the paper from a

feed of shredded plastic bottles with a loss of plastic with the paper of only zero to one percent.

It is a feature of the present invention to separate shredded paper from shredded plastic.

It is another feature of the present invention to purify recycled plastic from post-consumer waste.

It is a further feature of the present invention to provide an air density separation apparatus for separating sand, dirt and wood dust from wood chips.

It is a still further feature of the present invention to provide a method wherein post-consumer plastic waste may be purified for recycling.

It is a yet further feature of the present invention to provide an apparatus for feeding and distributing a granular material into an air stream.

Further objects, features and advantages of the invention will be apparent from the following detailed description when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side-elevational somewhat schematic view of the low velocity air density separator of this invention.

FIG. 2 is an isometric view, partly cut away, of the separation chamber and infeed mechanism of the low velocity air density separator of FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring more particularly to FIGS. 1-2 wherein like numbers refer to similar parts, a low velocity air density separator 20 is shown in FIG. 1.

The air density separator 20 has a vertically disposed conduit 22 which defines a vertical air separation chamber 24. Mixed particulate matter 44 is introduced into the separation chamber 24 from a material hopper 58. The air separation chamber 24 is connected by a duct 26 to a cyclone 28. The cyclone is connected to a fan 30. The fan draws air from the cyclone 28 which in turn draws air through the duct 26 which causes a stream of air indicated by arrows 32 to enter the bottom 34 of the conduit 22.

The mixed material 44 is discharged from the hopper 58 along an inclined chute 60 onto a foraminous screen formed by a grill 36 disposed within the separation chamber 24. The grill 36 has a multiplicity of closely spaced narrow bars 38 which extend across the conduit 22 between a material inlet 40 and a trash outlet 42. The grill 36 is cantilevered from a mount 46 which resiliently supports the grill 36 on springs 48. A ferromagnetic member 50 is mounted to the grill 36 and is driven by a solenoid 52 to cause the grill 36 to vibrate at about sixty Hertz. Certain material will be entrained in the upwardly moving air and will leave the separation chamber through the duct 26. The remaining particulate material which is not entrained and which is of a size to pass through the grill 36 will exit the separation chamber 24 through the bottom 34 of the conduit 22 and will be collected on a conveyor 35.

In a conventional air density separator, air is drawn up through the separation chamber at four to five thousand feet per minute while the granular material to be separated such as wood chips is dispensed into the air chamber either by a chute with an air lock or by an auger which distributes the material across the separation chamber. In a conventional air density separator the high velocity air stream moving up through the separation chamber is effective to disperse the granular material being separated in the air stream. Materials which are sufficiently dense fall down through the separation chamber whereas lighter materials become entrained in the air and are drawn into a cyclone where they are separated.

An air density separator separates a particulate matter depending on what is known in the aerodynamic field as ballistic coefficient. Ballistic coefficient is a function of the density of the object, the area of the object presented to the air stream, and a shape-dependent coefficient. Thus, the ballistic coefficient of an object increases with its density, decreases with increasing area and decreases with increasing bluntness of the object facing the air stream. Ballistic coefficient controls the maximum rate at which an object will fall through a still column of air. Because the resistance of an object through the air increases with velocity, an object which is accelerated by the earth's gravitational force eventually reaches a velocity where the acceleration force of gravity is balanced by the drag force of the air through which the object is moving.

This principal is used to separate the granular material into two or more components based on the ballistic coefficient of the granules. By introducing the granules into an upwardly moving stream of air which has a velocity which is greater than the terminal velocity of some of the particles and less than the terminal velocity of other particles, the granular material will be separated into two fractions. Thus, for separating wood chips from wood knots, an air velocity in the range of four to five thousand feet per minute is chosen which exceeds the terminal velocity of the wood chips, thereby causing them to rise to the top of the air chamber and be transported through a duct to a cyclone. On the other hand, the knots, which have a terminal velocity greater than four to five thousand feet per minute, fall through the air to exit the bottom of the separation chamber.

An exemplary problem addressed by the low velocity air density separator 20 is separating shredded paper from shredded plastic. The recycling of post-consumer plastic bottles has resulted in a feed stock formed by the shredding of plastic milk bottles or plastic pop bottles. The feed stock contains both plastic from the bottles and paper from the labels associated with the bottles. In order to make the feed stock a product with an economic value, it is necessary to separate the paper from the plastic. Because the plastic shards 54 as seen in FIG. 2 are of a thicker gauge of material than the paper or light grade plastic labels, they have a higher ballistic co-efficient and can be separated in theory in an air density separator. However, both the plastic and the paper are of relatively low ballistic coefficient and so the velocity of the air in the air density separator must be in the range of five hundred to a thousand feet per minute, preferably in the range of seven to eight hundred feet per minute. The problem with these low velocities can be readily demonstrated by taking a handful of paper confetti such as the punchings from a paper punch and dropping them into the air. Some of the paper punchings will become dispersed and rapidly reach their terminal velocity and slowly settle to the floor. Others, however, will clump together and fall as a unit reaching the floor first. Thus, it is observed with lightweight materials, they must be adequately dispersed in the column of air moving up through the vertical separation chamber 24 if it is desired to reliably separate them on the basis of their ballistic coefficients.

In the air density separator 20 proper dispersion is accomplished by the grill 36 formed of closely spaced narrow bars 38. In a chamber having dimensions of approximately fourteen inches by twenty-six inches, the bars 38 would have a depth of one and a half inches with a thickness of one and a half to three millimeters and a bar to bar gap of between one-eighth and one-fourth of an inch when used with a shredded material 44 having an average size of one-quarter inch to one half inch.

The bars 38 are formed into the grill 36 within a frame 64. One or more transverse reinforcements (not shown) may be installed on the underside of the grill 36 formed by the bars 38.

A low velocity air density separator 20, as shown in FIG. 1, was constructed with a fan 30 of five horse power capability. Table 1 lists the performance parameters of the five horse power fan. The suction pressure head was measured at the fan 30. This measurement was used to estimate the velocity in feet per minute and the flow rate in cubic feet per minute through the separation chamber 24. Tests were run with shredded plastic containing paper to determine the optimal fan operating level which would effect a clean separation between the paper and the plastic.

TABLE 1

Suction Pressure Head	Air velocity (Ft./Minute)	Flow rate (CFM)
@ 1" of H_2O	869	2,140
@2" of H_2O	825	2,030
@3" of H_2O	784	1,530
@4" of H_2O	739	1,800
@5" of H_2O	695	1,710
@6" of H_2O	656	1,615
@7" of H_2O	609	1,500
@8" of H_2O	559	1,375

For the particular system employed, which has an air separation chamber 24 with internal dimensions of 13.75 inches by 25.75 inches, a static head at the fan of four inches of water was found to produce a good separation between the paper and the plastic.

As shown in FIG. 2, shredded plastic and paper is fed on the chute 60 onto the deck 62 of the grill 36. The chute 60 extends partially over the grill 36 within the separation chamber. To prevent buildup of material on portions of the grill not within the chamber a cover 63 may be provided. The vibrating grill 36 disperses the granular material across the deck. The air stream which passes up through the bars 38 of the deck lofts the lightweight paper 56 and entrains it in the flow of air. The heavier plastic 54 slides through the bars and drops out the open end of the duct 22.

TABLE 2

	PAPER	PLASTIC
1500#/HR	5.8%	94.2%
2000#/HR	5.7%	94.3%
2500#/HR	5.3%	94.7%

Table 2 summarizes the results of three tests which were run with twenty pound samples in the air density separator 20. When a shredded mixture of plastic and paper having a bulk density of 18.5 pounds per cubic foot was fed at a rate of fifteen hundred pounds per hour into the separation chamber, 5.8 percent of the material was recovered from the cyclone as paper and 94.2 percent was recovered from the bottom of the separation chamber and consisted of plastic.

Similarly, the test was run at feed rates of two thousand pounds per hour and twenty-five hundred pounds per hour. A slightly lesser amount of paper was recovered at the higher rates. It appears separation of the paper from the plastic is slightly less effective at higher rates. Visual inspection of the separated plastic and paper indicated that approximately ninety-five to ninety-eight percent of the paper was removed from the plastic and only zero to one percent of the plastic was lost with the removed paper.

The air density separator 20 inlet 40 does not require an air lock because of the relatively low velocity of the air. The relatively small effect that openings in the wall 70 of the conduit 22 have on the stream is utilized to allow an oversize tray 72 to extend from the deck 62 of the grill 36 through the wall 74 opposite the inlet wall 70. Trash which has become included in the granular material 44 traverses the sloped grill 36 and exits the duct 22 on the chute 72 which directs the trash for collection in a reject bin 78, as shown in FIG. 1.

The cyclone 28 uses centrifugal forces to separate the majority of the particulate material from the air stream. The cyclone has an air lock 80 which allows the paper to be removed from the cyclone. The air that is withdrawn from the cyclone passes through the fan and then into a bag house (not shown) where any residual dust is removed before venting to the atmosphere.

It should be understood that the low velocity air density separator 20 may employ a foraminous member of configuration other than a grill of narrow bars. For example, the foraminous member could be a vibrating screen, or a vibrating plate with holes punched therein. In addition, the foraminous member could consist of an interdigitating bar screen with alternating bars oscillating one hundred eighty degrees out of phase with respect to adjacent bars.

It should also be understood that although a separation chamber 24 of approximately 10 feet in height has been illustrated, the separation chamber may be shorter or longer.

It should also be understood that the low velocity air density separator may be used to separate products other than shredded post-consumer plastic containers. For example, the density separator 20 has utility for separating dirt and sand from wood chips.

It should be understood that wherein the term vibration is used, it is not limited to the vibratory action in a vertical plane produced by the solenoid arrangement shown in FIGS. 1 and 2 but encompasses vibrating in all planes and oscillatory motion such as employed by a bar screen.

It should be understood that although coil springs are shown resiliently mounting the grill foraminous member 36 for vibration, other mounts, for example leaf springs, are acceptable.

It should further be understood that wherein a solenoid driven by sixty hertz line frequency causes the foraminous member to vibrate at sixty hertz, the grill 36 could be caused to vibrate at other frequencies and other mechanisms for causing the vibration could be employed including a drive employing eccentric weights, cam followers on a crank shaft, piezoelectric actuators and systems caused to vibrate by high amplitude low frequency air pressure waves including sound waves.

It is understood that the invention is not limited to the particular construction and arrangement of parts herein illustrated and described, but embraces such modified forms thereof as come within the scope of the following claims.

Claims

1. An apparatus for separating mixed particulate material comprising:

a substantially vertically extending conduit having walls with a top and a downwardly open bottom, the walls defining a passage for the upward flow of air;

a duct connected to the top of the conduit and joined thereto so as to allow air to be drawn up through the conduit;

a fan connected to the duct which draws air thorough the conduit;

a foraminous member extending into the conduit and into the air passage; and

a means for vibrating the foraminous member, wherein mixed particulate material discharged onto the foraminous member is thus dispersed into an upwardly moving air stream within the conduit, certain particles being entrained in the air and transported out of the conduit upwardly, and other particles passing through the foraminous member to exit the conduit bottom.

2. The apparatus of Claim 1 wherein the foraminous member comprises a plurality of narrow bars arrayed in spaced

parallel relation.

3. The apparatus of Claim 2 wherein the bars forming the grill are between one and a half and three millimeters wide and are spaced apart between one-eighth and one-quarter of an inch.

4. The apparatus of Claim 1 wherein the foraminous member is resiliently mounted externally to the conduit and slopes downwardly into the conduit.

5. The apparatus of Claim 1 further comprising a feed chute extending into the duct and positioned above the foraminous member for delivering mixed particulate material to the foraminous member.

6. The apparatus of Claim 1 further comprising a cyclone connected between the duct and the fan.

7. The apparatus of Claim 1 wherein the conduit walls define a cross-sectional area, and wherein the fan has the capability of drawing between five hundred and one thousand cubic feet of air per minute per square foot of cross-sectional area of the conduit when running at its maximum capability.

8. The apparatus of Claim 1 wherein the means for vibrating the foraminous member is a solenoid which magnetically engages the foraminous member causing it to vibrate.

9. The apparatus of Claim 1 wherein the conduit has a material inlet and a material outlet beneath and opposed to the inlet, and wherein the foraminous member extends between the inlet and the outlet and slopes downwardly from the inlet to the outlet so that granular material placed on the foraminous member which neither falls through the foraminous member nor is entrained in a stream of air moving up through the conduit progresses along the foraminous member from the inlet to the outlet for discharge from the conduit.

10. The apparatus of Claim 1 wherein the conduit has a rectangular cross-section and wherein the foraminous member has an a surface area substantially equal to or greater than the cross-section of the conduit.

11. A method for separating a granular material comprising the steps of:

delivering a stream of granular material to a vibrating foraminous member enclosed in a duct, wherein the granular material has at least two components having differing terminal velocities; and
drawing a current of air up through the duct at a velocity of between 500 and 1000 feet per minute such that at least a portion of the air passes through the foraminous member, wherein the air passing through the foraminous member disperses the granular material so it may be separated on the basis of its terminal velocity in the current of air.

12. The method of Claim 11 wherein the granular material being separated is comprised of post-consumer plastic articles which are shredded to form the granular material and wherein a first component is comprised of shards of plastic and a second component is comprised of a thinner materia! having a lower terminal velocity.

13. An apparatus for separating a mixed particulate material having at least two components of differing terminal velocities, the apparatus comprising:

a substantially vertically extending conduit having a bottom open to the atmosphere and a top which is connected to a duct, so that a stream of air may be drawn from the bottom to the top of the conduit;
a grill of narrow bars arrayed in spaced parallel relation which extends into the conduit, wherein the grill is resiliently mounted exterior to the conduit such that the bars slope downwardly into the conduit,
a means for causing the grill to vibrate mounted externally to the conduit and in driving relation with the grill;
an infeed chute extending into the duct above the grill which delivers mixed particulate material having at least two components of differing terminal velocities to the grill;
a cyclone in receiving relation with the duct at the top of the conduit, wherein the component of the mixed particulate material having a lower terminal velocity is entrained in the air received in the cyclone is separated from the air therein;and
a fan connected to the cyclone for pulling the stream of air through the conduit and the cyclone.

14. The apparatus of Claim 13 wherein the bars forming the grill are between one and a half and three millimeters

wide and are spaced apart between one-eighth and one-quarter of an inch.

15. The apparatus of Claim 13 wherein the grill is resiliently mounted externally to the conduit and slopes downwardly into the conduit.

16. The apparatus of Claim 13 wherein the conduit walls define a selected cross-sectional area, and wherein the fan has the capability of drawing between five hundred and one thousand cubic feet of air per minute per square foot of cross-sectional area of the conduit when running at its maximum capability.

17. The apparatus of Claim 13 wherein the means for vibrating the grill is a solenoid which magnetically engages the grill causing it to vibrate.

18. The apparatus of Claim 13 wherein the conduit has a material inlet and a material outlet beneath and opposed to the inlet, and wherein the grill extends between the inlet and the outlet and slopes downwardly from the inlet to the outlet so that material placed on the grill which neither falls through the grill nor is entrained in a stream of air moving up through the conduit progresses along the grill from the inlet to the outlet for discharge from the conduit.

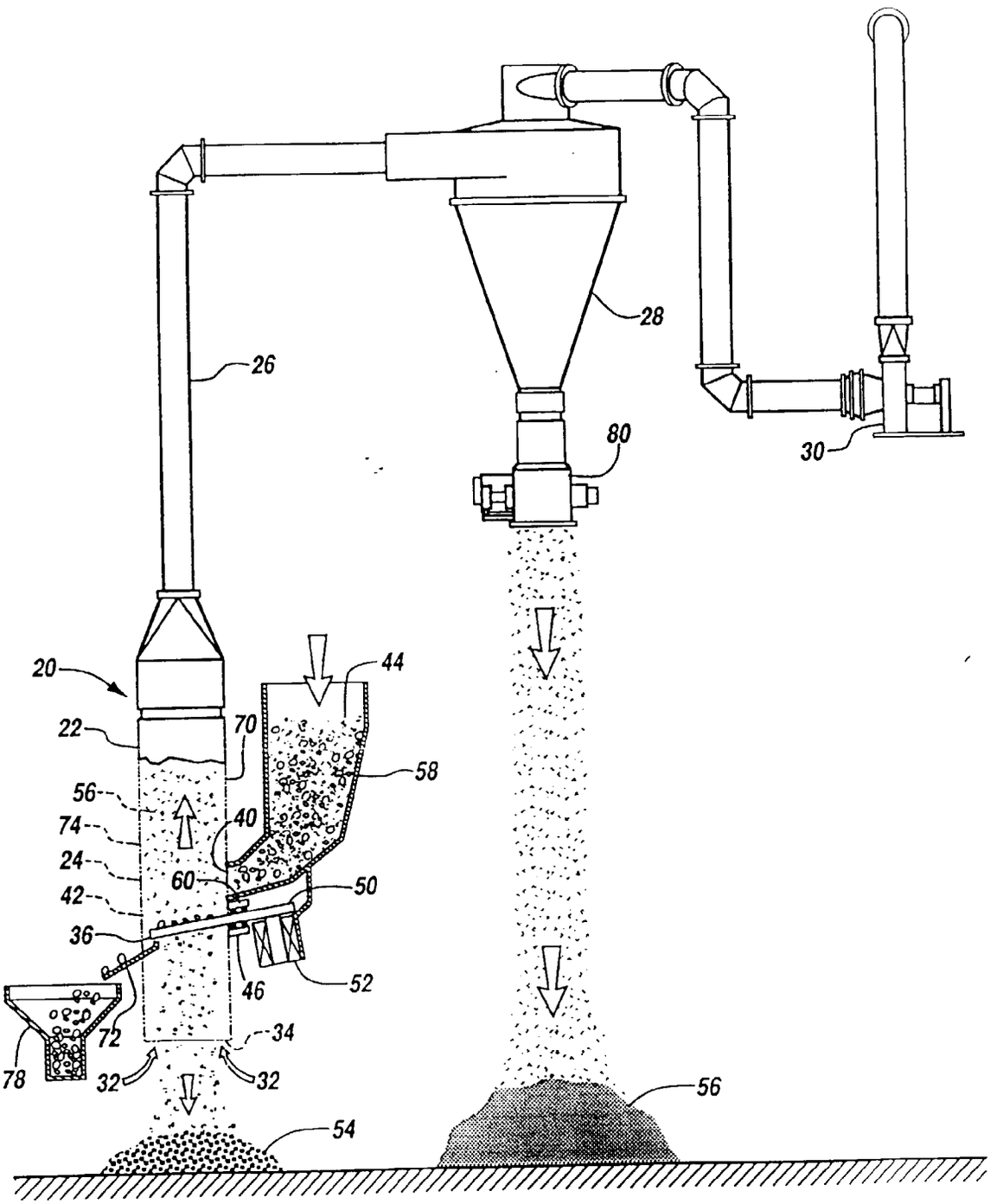
20
22
70
44
58
56
74
40
24
60
50
42
36
46
52
72
34
78
32
32
54
56
26
28
80
30

Fig.1

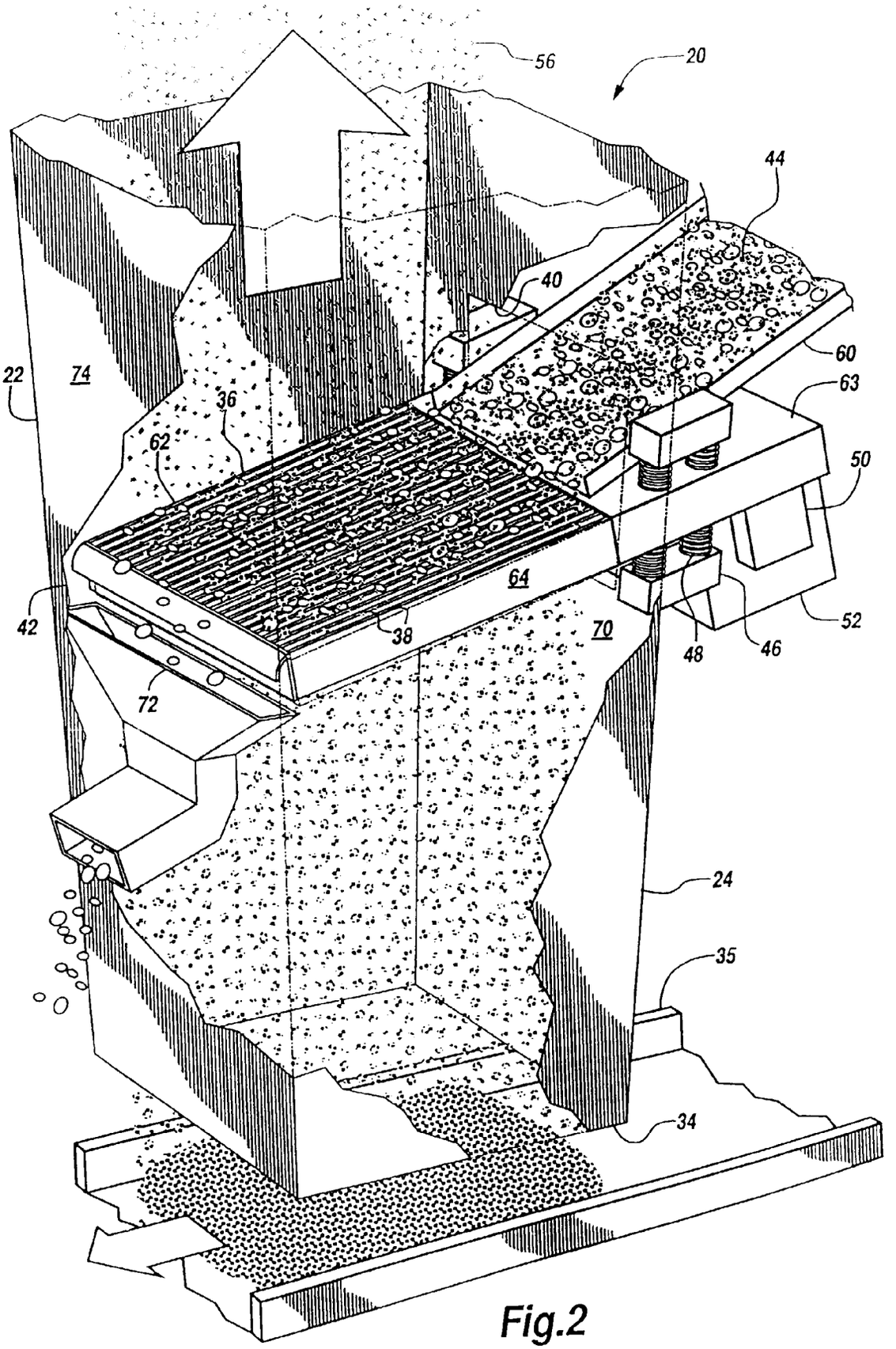

Fig.2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 63 0074

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	US 4 280 903 A (SCHOLTEN) * column 2, line 28 - column 4, line 33; figure 1 *	1,5,6	B07B4/08 B07B9/00
Y		2,4,7,9,11	
A		10,13,16,18	

Y	EP 0 615 786 A (NORSK HYDRO TECHNOLOGY B.V.) * column 2, line 20 - column 3, line 33; figures *	2,9	
A		1,5,11,13,18	

Y	DE 195 08 314 A (AGENCY OF INDUSTRIAL SCIENCE AND TECHNOLOGY) * column 3, line 8 - line 38; figures *	4	
A		1,5,7,9-11,13,15,16,18	
	---		TECHNICAL FIELDS SEARCHED (Int.Cl.6)
Y	US 4 299 694 A (GOODELL) * column 2, line 51 - column 3, line 38 * * column 4, line 29 - line 45; figures *	7,11	B07B D21B
A		1,2,5,6,10,13,16	

Y	US 2 852 137 A (HAGOPIAN) * column 1, line 68 - column 2, line 46 * * column 3, line 45 - column 4, line 5; figures *	1,5,6,9,10	
A		4,7,11,13,15,16,18	

	-/--		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 April 1997	Van der Zee, W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 96 63 0074

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	US 2 200 472 A (ERDMANN) * the whole document *	1,5,6,9,10	
A		4,7,11,13,15,16,18	

A	DE 31 26 585 A (RHEINISCHE BRAUNKOHLENWERKE AG) * page 15, line 3 - page 16, line 15; figure 2 *	1,4,5,8,11,13,15,17	

			TECHNICAL FIELDS SEARCHED (Int.Cl.6)

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	2 April 1997	Van der Zee, W

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)