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

(11) Publication number: 0 283 682 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 88101623.2

(51) Int. Cl.⁴: B02C 23/32 , B02C 15/00

(22) Date of filing: 04.02.88

A request for correction has been filed pursuant to Rule 88 EPC. A decision on the request will be taken during the proceedings before the Examining Division (Guidelines for Examination in the EPO, A-V, 2.2).

(30) Priority: 24.03.87 JP 67907/87
24.03.87 JP 67908/87
20.07.87 JP 179005/87

(43) Date of publication of application:
28.09.88 Bulletin 88/39

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

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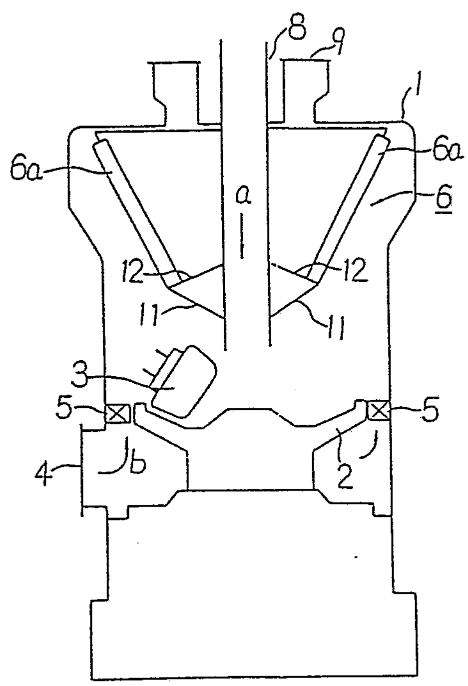
(54) **Roller mill.**

(57) The known roller mill associated with a rotary-type classifier is improved in a number of aspects. The improvements reside in that a downwardly convex flow-rectifying cone is disposed under the rotary type classifier and an upwardly convex slant plate for ejecting a sediment within the classifier is disposed above the flow-rectifying cone; that a baffle plate for hot air which covers a part of an upper side of a blow-up passageway of hot air provided along the outer circumferential portion of a turn table as spaced therefrom; or that the rotary classifier comprises a plurality of classifying blades disposed along generating lines of an inverse frusto-conical surface having a vertical axis and rotating about the axis to separate powder in a gas flow into fine powder and coarse powder, an angle formed between the classifying blade and a rotary radius is selected to be 30° to 60°, and an angle formed between the classifying blade and the rotary axis is selected to be 0° to 40°; either singly or in combination.

Fig. 1



ROLLER MILL

BACKGROUND OF THE INVENTION:

Field of the Invention:

The present invention relates in general to a roller mill, and more particularly to a roller mill associated with a rotary-type classifier that is available for pulverizing coal to be used in a pulverized coal fired boiler, for pulverizing clinker to produce cement or for similar purposes.

Description of the Prior Art:

At first, description will be made on one example of the above-described roller mill associated with a rotary-type classifier in the prior art with reference to Fig. 14. The illustrated roller mill has such structure that within a mill main body (1) is disposed a table (2) which is turned by a vertical drive shaft (not shown), a plurality of rollers (3) which are rotated while being pressed against the upper surface of the table (2) to crush material (a) to be pulverized are disposed to the table (2), a rotary-type classifier (6) is disposed above the table (2), thereby the material (a) to be pulverized such as lump coal thrown into the mill through a feed pipe (8) is pressed on the turning table (2) by means of the respective rollers (3) to crush it under a given load and eject it to the outer circumference of the same table, hot air (b) introduced through a hot-air inlet (4) at the below is fed in association with the pulverized material through a blow-up section (5) opened along the entire outer circumference of the table (2) into the mill main body on the upper side of the table, thus the pulverized material is sent to the rotary-type classifier (6) at the above by the hot air, that is, the rising carrier gas, then the above-mentioned pulverized material is classified into coarse powder and fine powder by means of rotary blades (6a), the fine powder is derived through a discharge pipe (9) while the coarse powder is ejected to the outside of the classifier and falls on the table (2) to be crushed again, and the bottom portion of the rotary-type classifier is formed of a flat bottom plate (6b).

In the above-described roller mill, the coarse powder ejected to the outside of the rotary-type classifier is classified in weight by the rising carrier gas blown up from the lower portion of the mill, and a principle of the weight-classification is based on the Stokes' Law and represented by the following formula:

$$\mu_t = g\ (\rho_s - \rho_g)\ d_p{}^2/18\ \mu g$$

where

μ_t: terminal sedimentation velocity of particles with respect to a gas flow [cm/sec]

μ μg: rising velocity of a gas flow [cm/sec]

g: gravitational acceleration [cm/sec]

ρ_s: density of solid; ρ_g: density of gas dp: particle diameter.

When the terminal sedimentation velocity μ_t of particles with respect to the gas flow is equal to the rising velocity μ_g of the gas flow, that is, $\mu_t = \mu_g$ is fulfilled, the particles appear to be still as viewed from the outside, but if $\mu_t < \mu_g$ is fulfilled, the particles appear to rise, while if $\mu_t > \mu_g$ is fulfilled, then the particle would appear to descend.

The above-described roller mill associated with a rotary-type classifier in the prior art involved the problems that a swirl would be generated under the flat bottom plate of the rotary-type classifier, flow velocities of air would become irregular at the inlet of the rotary blades, hence a classification performance is greatly deteriorated by the irregularity of the air flow velocities at the inlet of the rotary blades because the rotary-type classifier utilizes the mechanism of classifying into coarse powder and fine powder on the basis of the balance between a centrifugal force given by the rotation of the rotary blades and a centripetal force given to particles by an air flow, also fine powder would settle and pile on the flat bottom plate, and if it continues to pile over a long period of time, in the case of pulverized coal, it may cause autogeneous ignition or explosion.

In addition, the above-described roller mill in the prior art involved an additional problem that while the coarse powder classified by the rotary blades of the rotary-type classifier and ejected to the outside is necessitated to be made to fall on the table and to be crushed again, due to the fact that the coarse powder consists of particles raised by rising carrier gas and the rising velocity of the rising carrier gas is almost equal at every location along a radial direction and a circumferential direction on the transverse cross-section of the mill, the above-mentioned coarse powder would hardly fall on the table, as a result a powder density within the mill becomes high, a pressure loss within the mill is increased, the interior of the mill becomes a fluidized bed, resulting in a large pressure variation, and this brings about large adverse effects upon a pulverizing performance.

Furthermore, in the rotary-type classifier provided in the roller mill in the prior art, despite of the fact that a mount angle of the classifying blades is an important factor largely influencing upon a classifying performance and hence there must be an optimum range therefor, heretofore this mount angle was determined without relying upon any definite ground.

SUMMARY OF THE INVENTION:

It is therefore one object of the present invention to provide an improved roller mill associated with a rotary-type classifier that is free from the above-described shortcomings in the prior art.

A more specific object of the present invention is to provide a roller mill associated with a rotary-type classifier, in which a classifying performance and an operational reliability are greatly improved, and a safety is so enhanced that autogeneous ignition or explosion within a classifier can be prevented.

Another object of the present invention is to provide a roller mill associated with a rotary-type classifier, in which a pressure loss within the mill and an amplitude of a pressure variation are largely reduced, and a pulverizing performance and an operational reliability are greatly improved.

A still another object of the present invention is to provide a roller mill associated with a rotary-type classifier, in which a mount angle of the classifying blades can be chosen at an optimum value, and thereby classification of pulverized material into coarse powder and fine powder can be achieved efficiently.

According to one feature of the present invention, there is provided a roller mill associated with a rotary-type classifier, including a table disposed within a mill main body and turned by a vertical drive shaft, a plurality of rollers rotated as pressed against the upper surface of the table to crush material to be pulverized in cooperation with the table, and a rotary-type classifier disposed above the table for classifying pulverized material in a rising carrier gas, in which a downwardly convex flow-rectifying cone is disposed under the rotary-type classifier, and an upwardly convex slant plate for ejecting a sediment within the classifier is disposed above the flow-rectifying cone.

According to another feature of the present invention, there is provided a roller mill associated with a rotary-type classifier, including a table disposed within a mill main body and turned by a vertical drive shaft, a plurality of rollers rotated as pressed against the upper surface of the table to crush material to be pulverized in cooperation with the table, and a rotary-type classifier disposed above the table for classifying pulverized material in a rising carrier gas, in which a baffle plate for hot air which covers a part of an upper side of a blow-up passageway of hot air provided along the outer circumferential portion of the table as spaced therefrom, is disposed above the blow-up passageway of hot air.

According to still another feature of the present invention, there is provided a roller mill associated with a rotary-type classifier, including a table disposed within a mill main body and turned by a vertical drive shaft, a plurality of rollers rotated as pressed against the upper surface of the table to crush material to be pulverized in cooperation with the table, and a rotary-type classifier disposed above the table for classifying pulverized material in a rising carrier gas, in which the rotary-type classifier comprises a plurality of classifying blades disposed along generating lines of an inverse frusto-conical surface having a vertical axis and rotating about the axis to separate powder in a gas flow into fine powder and coarse powder, an angle formed between the classifying blade and a rotary radius is selected to be 30° to 60° and an angle formed between the classifying blade and a rotary axis is selected to be 0° to 40°.

In operation of the roller mill according to one aspect of the present invention, the rising carrier gas accompanied by the pulverized material flows into an inlet of rotary blades after it has been rectified in flow by the downwardly convex flow-rectifying cone disposed under the rotary-type classifier, hence generation of a swirl under the rotary-type classifier is eliminated, a flow velocity of the rising carrier gas at the inlet of the rotary blades is made to be uniform, the classification of pulverized material by means of the rotary blades becomes smooth, then the fine powder settling within the rotary-type classifier is made to slip down along the upwardly convex slant plate and ejected to the outside of the classifier, and it is mixed with the rising carrier gas and then classified again.

In operation of the roller mill according to another aspect of the present invention, hot air passed through a blow-up passageway provided along the outer circumferential portion of the table within the mill main body becomes a rising carrier gas as accompanied by pulverized material ejected to the outer circumference of the table, a part of the rising carrier gas strikes against the baffle plate and is diverted thereby, upon that diversion coarse particles are primarily classified and caused to fall on the table, and after the diversion a part having a high rising velocity and a part having a low velocity are produced in the rising carrier gas within the mill main body, then the part having a low rising velocity becomes a falling passageway for the coarse powder classified by the classifier, and the above-mentioned coarse powder would fall smoothly on the table jointly with the coarse particles.

In operation of the roller mill according to still another aspect of the present invention, owing to the specifically defined attitude of the classifying blades in the rotary-type classifier, separation between fine powder and coarse powder can be carried out efficiently, and the rising carrier gas accompanied by the pulverized material can smoothly flow into the space surrounded by the classifying blades.

Hence, according to the present invention, various advantages are provided such that besides safety of the roller mill, a classifying performance as well as an operational reliability of the roller mill can be improved, that a pulverizing efficiency can be greatly enhanced, by largely reducing a pressure loss and an amplitude of pressure variation within the mill, and that a separation efficiency between fine powder and coarse powder in the rotary-type classifier can be remarkably improved.

The above-mentioned and other objects, features and advantages of the present invention will become more apparent by reference to the following description of preferred embodiments of the present invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS:

In the accompanying drawings:

Fig. 1 is a schematic longitudinal cross-section view showing a first preferred embodiment of the present invention;

Fig. 2 is a diagram showing results of classification tests for different inclination angles of a slant plate;

Fig. 3 is a schematic longitudinal cross-section view showing a second preferred embodiment of the present invention;

Fig. 4 is a schematic transverse cross-section view taken along line IV-IV in Fig. 3 as viewed in the direction of arrows;

Fig. 5 is an enlarged partial cross-section view taken along line V-V in Fig. 4 as viewed in the direction of arrows;

Fig. 6 is a diagram showing distribution of relative velocities of a rising air flow along a radial direction of a mill;

Fig. 7 is a diagram showing distribution of relative velocities of a rising air flow along the circumferential direction of the mill;

Figs. 8(A) and 8(B) are, respectively, schematic longitudinal cross-section views showing a third preferred embodiment of the present invention;

Fig. 9 is a perspective view partly cut away of a rotary-type classifier in the roller mill according to the third preferred embodiment;

Fig. 10 is a schematic transverse cross-section view taken along line X-X in Fig. 8(A) as viewed in the direction of arrows;

Figs. 11 through 13 are diagrams showing the effects and advantages of the third preferred embodiment; and

Fig. 14 is a schematic longitudinal cross-section view of a roller mill associated with a rotary-type classifier in the prior art.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

A first preferred embodiment of the present invention is illustrated in Fig. 1, in which reference numeral (1) designates a mill main body, numeral (2) designates a table, numeral (4) designates an inlet of hot air, numeral (5) designates a blow-up section of hot air, numeral (6) designates a rotary-type classifyer, numeral (8) designates a feed pipe of material (a) to be pulverized, and numeral (9) designates a discharge cylinder of fine powder. The construction of the roller mill associated with a rotary-type classifier which forms a subject matter of the present invention, is such that in a roller mill including a table (2) disposed within a mill main body (1) and turned by a vertical drive shaft (not shown), a plurality of rollers (3) rotated as pressed against the upper surface of the table (2) to crush material (a) to be pulverized in cooperation with the table (2), and a rotary-type classifier (6) disposed above the table for classifying pulverized material in a rising carrier gas, a downwardly convex flow-rectifying cone (11) is disposed under the rotary-type classifier (6), and an upwardly convex slant plate (12) for ejecting a sediment within the classifier is disposed above the flow-rectifying cone (11). The inclination angle of the above-mentioned slant plate (12) is selected in correspondence to a slip angle of the sediment and preferably to be a little steeper than the corresponding angle, the slant plate (12) rotates about the feed pipe (8), and the flow-rectifying cone (11) also can be made to likewise rotate.

Now description will be made on the operation of the preferred embodiment of the present invention having the above-mentioned construction.

The material (a) to be pulverized such as lump coal charged through the feed pipe (8) is pressed by the plurality of rollers (3) on the rotating table (2), thus applied with a load to be crushed, and ejected to the outer circumferential portion of the table (2), then hot air (b) introduced through the hot air inlet (4) at the below passes through the blow-up section (5) and becomes a rising carrier gas as accompanied by the ejected pulverized material, this rising carrier gas rises through the inner space of the mill main body (1) above the table (2), flows into an inlet section of rotary blades (6a) after it has been rectified in flow by the downwardly convex rectifying cone (11), and since generation of a swirl under the rotary-type classifier (6) is almost eliminated by the rectifying cone (11) and flow velocities of the rising carrier gas at the inlet section of the rotary blades (6a) are made to be uniform, the pulverized material in the rising carrier gas can be classified smoothly and efficiently by the rotary blades (6a), and thereby a classifying performance into coarse powder and fine powder can be greatly enhanced.

The classified fine powder is derived through the discharge cylinder (9) jointly with the carrier gas, while the coarse powder is ejected to the outside of the classifier by the rotary blades (6a) and falls on the table (2), and then it is crushed again.

It is inevitable that a part of coarse powder flows into the inside of the rotary blades (6a), that is, to within the rotary-type classifier (6) jointly with fine powder, and so, within the rotary-type classifier (6) a sediment of fine powder or the like is liable to be produced. However, this sediment would slip down to the circumference due to existence of the upwardly convex slant plate (12), thus it would be ejected to the outside of the classifier within the mill main body (1) and mixed with the rising carrier gas to be reclassified, and thereby accumulation of a sediment within the classifier can be prevented.

Regarding the inclination angle of the slant plate (12), that is, the slip angle in the case of coal, the slip angle of coal is different depending upon a variety of coal as indicated in Table-1 below, for instance, in the case of Chinese coal (E) having a slip angle of 25.4 degrees, it is preferable to select the inclination angle of the slant plate (12) to be about 30°, and if the slant plate (12) is rotated, slip-down of the sediment becomes smooth.

Results of tests of a classifying performance for different inclination angles θ_1 of the slant plate (12) are shown in Fig. 2 (in this example, evaluation is made on the basis of an amount of particles having a particle diameter of 149 µm or larger which form coarse granular material in the product coal), and according to the test results in Fig. 2, the above-mentioned inclination angle θ_1 with respect to the horizontal plane provides an optimum result at 30 - 60 degrees. If the inclination angle θ_1 becomes larger than 60 degrees, though degradation of a classifying performance is relatively small, the vertical length of the slant plate (12) would become remarkably large and hence would be unfavorable in view of arrangement within the mill, and so, the improvement of the classifying performance is supplemented by rotation of the slant plate (12).

In Table-2 below are shown results of tests for a classifying performance in the case of the mill in the prior art and in the case of the mill according to the present invention in terms of grain size distributions of the product coal (pulverized coal at the outlet of the mill). In the case of the mill according to the present invention, for the same rotational speed of the classifier, the amount of particles having a grain size 74 µm or smaller is more by about 2%, and the amount of coarse particles having a grain size of 149 µm or larger which adversely affect the combustibility is reduced to less than one-half. In this case, the rotational speed of the classifier can be made to be lower by about 20%, and this is an effect brought about by equalization of an air velocity distribution at the inlet of the classifier caused by the flow-rectifying cone (11) and ejection and reclassification of a sediment caused by the slant plate (12).

Accumulation of fine powder or the like at the lower portion within the classifier becomes almost undetectable, and it has been confirmed that the mill can be operated safely without the fear of autogeneous firing or explosion caused by accumulation of fine powder or the like at all.

Table-1

	Domestic (Japanese) Coal (A)	Domestic (Japanese) Coal (B)	Australian Coal (C)	Australian Coal (D)	Chinese Coal (E)	American Coal (F)
Slip Angle	36.7	19.6	46.2	15.8	25.4	32.5

Table-2

		Mill in the Prior Art	Mill According to the Present Invention
Rotational Speed of Classifier 80 r.p.m.	74 µm or smaller	81.5 %	83.2 %
	149 µm or larger	1.0 %	0.4 %
Rotational Speed of Classifier 100 r.p.m.	74 µm or smaller	88.2 %	90.5 %
	149 µm or larger	0.4 %	0.0 %

A second preferred embodiment of the present invention is illustrated in Figs. 3 to 5, in which reference numeral (1) designates a mill main body, numeral (2) designates a table that is turned by a vertical drive shaft (not shown), numeral (3) designates rollers rotated as pressed against the upper surface of the table (2), numeral (4) designates an inlet of hot air, numeral (8) designates a feed pipe of material to be pulverized, numeral (9) designates a discharge cylinder, numeral (5) designates a blow-up passageway of hot air disposed locally on the outer circumferential portion of the table (2), and numeral (6) designates a rotary type classifier disposed in the upper portion within the mill main body (1). The construction is such that the mill includes a table (2) disposed within the mill main body (1) and a plurality of rollers (3) rotated as pressed against the upper surface of the table (2) to crush material to be pulverized, a blow-up passageway (5) of hot air is disposed on the outer circumferential portion of the table (2), and a baffle plate (20) for hot air covering a part of the upper side of the blow-up passageway (5) as spaced therefrom is disposed above the blow-up passageway (5).

In more particular, the above-mentioned blow-up passageways (5) are disposed in multiple (three in the illustrated case) between hot air shut-off plates (21) provided along the outer circumferential portion of the table (2), as spaced from each other in the circumferential direction as shown in Fig. 4, and the arrangement is such that hot air (b) may be passed towards the base side of a baffle plate (20) by means of a plurality of guide plates (15a) disposed in parallel to each other. As shown in Figs. 4 and 5, the above-described baffle plates (20) are disposed above the respective blow-up passageways (5) as spaced therefrom so as to cover a part of the upper side of the blow-up passageways (5), they are largely inclined and opened as directed in the turning direction of the table (2) (in the direction by an arrow) and also inclined and opened towards the center of the mill, hot air passed through the respective blow-up passageways (5) becomes a rising carrier gas accompanied by the pulverized material ejected to the outer circumference of the table (2), a part of the above-mentioned rising carrier gas strikes against the lower surface of the baffle plate (20) and is diverted thereby, and then it flows out through the above-mentioned openings and becomes a rising carrier gas within the mill main body.

In the above-described rotary-type classifier (6), an upwardly convex slant plate (12) is disposed at the bottom end of rotary blades (6a), a downwardly convex flow-rectifying cone (11) is provided on the downside of the slant plate (12), hence the slant plate (12) and the flow-rectifying cone (11) rotate together, and thereby fine powder or the like (possibly including coarse powder) deposited on the inside of the rotary blades (6a) are made to slip down to the circumferential portion by the slant plate (12).

The second preferred embodiment of the present invention is constructed as described above, and now description will be made on the operation of the second preferred embodiment.

Material (a) to be pulverized such as lump coal charged through the feed pipe (8) is pressed by a plurality of rollers (3) on the turning table (2), applied with a load, crushed and then ejected to the outer circumference of the table (2). Hot air (b) introduced through the hot air inlet (4) at the below, is passed through the respective blow-up passageways (5), and becomes a rising carrier gas (b′) as accompanied by crushed material of the material (a) to be pulverized that is ejected to the outer circumferential portion of the table (2), then a part of the rising carrier gas (b′) strikes against the lower surface of the baffle plate (20) and is diverted thereby, and it passes through the openings on the side of the circumferential direction and on the side of the center of the mill and rises within the mill main body. When the above-mentioned carrier gas (b′) strikes against the lower surface of the baffle plate (20), coarse particles contained in the pulverized material are greatly diverted and fall on the table (2), and thereby primary classification is carried out.

Since the respective portions of the rising carrier gas (b′) are partly diverted by the corresponding baffle plates (20), a high rising velocity portion and a low rising velocity portion of the rising carrier gas are produced within the mill main body (1) on the upper side of the baffle plates (20). The rising velocity of the rising carrier gas is raised on the side of the center of the mill (X), whereas it is lowered on the side of the circumference of the mill (Y) as shown in Fig. 6, and also as shown in Fig. 7 high rising velocity portions and low rising velocity portions are produced alternately along the circumferential direction.

The rising carrier gas accompanied by the pulverized material rises within the mill main body, and is passed to the inside of the rotary blades (6a) after it has been rectified in flow by the flow-rectifying cone (11), the pulverized material in the rising carrier gas is classified by the rotary blades (6a) into coarse powder and fine powder, and the fine powder is derived through the discharge cylinder (9), while the coarse powder is ejected to the outside of the rotary-type classifier (6) by the action of the rotary blades (6a), then falls on the table (2) and is crushed again.

Since a high rising velocity portion and a low rising velocity portion as described above are produced in the rising carrier gas within the mill main body, the above-mentioned coarse powder would fall at the portion having a relatively low rising velocity, and thus a plurality of falling passageways are formed.

The above-mentioned falling passageways for coarse powder and partly formed in the rising carrier gas, hence they do not cause any special hindrance to the rise of the pulverized material caused by the high velocity portion, a pressure loss is greatly reduced, and the falling of coarse powder onto the table becomes smooth.

The upper surfaces of the hot air shut-off plate (21) and the respective baffle plates (20) are formed in slant surfaces having an inclination angle corresponding to a slip angle of the coarse powder in question but a little larger than the latter. For instance, in the case of coal a slip angle of at least 16 - 47 degrees is necessitated as shown in Table-1 above though it may be different depending upon varieties of coal. Hence it is preferable to select the inclination angle on the upper side of the hot air shut-off plate and the baffle plates to be equal to the slip angle in the table plus about 10 degrees, then the coarse powder, that is, the material to be pulverized would slip and fall onto the table (2) and would be crushed.

Although a most part of the coarse powder is separated and falls on the table (2) as described above, a part of the coarse powder would flow into the rotary-type classifier (6). On the inside of the rotary blades (6a), sedimentation of fine powder as well as coarse powder would occur, the sediment is made to slip and fall by the slant plate (12) and mixed with the rising carrier gas on the outside to be reclassified, and coarse powder would fall on the table (2) similary to the above-described primary classification.

As a result of comparative tests conducted for System-A in which while a hot air blow-up passageway is provided along the entire length of the outer circumference of the table (2), a slant plate (12) is provided in the rotary-type classifier but a baffle plate (20) is not provided, and System-B according to the above-described second preferred embodiment of the present invention, it was proved that a mill pressure loss and an amplitude of pressure variation are as indicated in Table-3 below, thus in the case of System-B embodying the present invention, a favorable result was obtained in that a pressure loss was reduced by about 30% and an amplitude of pressure variation was reduced to about one-half.

Table-3

	Syste-A	System-B (present invention)
Mill pressure loss	490mm H_2O	350mm H_2O
Pressure variation amplitude	±20mm H_2O	±10mm H_2O

Now a third preferred embodiment of the present invention will be described with reference to Figs. 8 to 10. This preferred embodiment provides further improvements on the first preferred embodiment shown in Fig. 1 as illustrated in Fig. 8(A) and on the second preferred embodiment shown in Figs. 3 to 5 as illustrated in Fig. 8(B) in that a classifying efficiency of the classifying blades in the rotary-type classifier is optimized, as will be described in the following. Hence, thus preferred embodiment includes component parts similar to those used in the first and second preferred embodiments, and the equivalent component parts are given like reference numerals.

In Figs. 8 to 10, reference numeral (10) designates an upper support plate for classifying blades (6a), a plurality of classifying blades (6a) are disposed along generating lines of an inverse frusto-conical surface having a vertical axis, and supported at their upper and lower ends by the upper support plate (10) and a downwardly convex flow-rectifying cone (11), and they are adapted to be rotated about a feed pipe (8) that is disposed along the vertical axis of the above-mentioned inverse frusto-conical surface. In the illustrated embodiment, an angle θ_3 (See Fig. 10) formed between the classifying blade (6a) and a rotary radius is selected to be 30° to 60°, and an angle θ_2 (See Fig. 8) formed between the classifying blade (6a) and the rotary axis is selected to be 0° to 40°. A principle of classification into coarse powder and fine powder by rotation of the classifying blades (6a) is based on the following two effects:

(A) Balance between the forces acting upon the particles having entered into the classifying blades:

As shown in Fig. 10, upon the particles within the blades act a fluid resistance R directed in the centripetal direction caused by an air flow and a centrifugal force F caused by the rotary motion, and the respective forces are represented by the following formulae:

$R = 3\pi d\mu V,$

$$R = 3\pi d\mu V_1$$

$$F = \frac{\pi}{6} \cdot d^3(\rho_1 - \rho_2)\frac{V_2^2}{r}$$

where

d: particle diameter [cm]

μ: viscosity of gas [poise]

V_1: velocity in the centripetal direction of gas [cm/sec]

V_2: circumferential velocity of blades [cm/sec]

ρ_1, ρ_2: densities of particles and gas [g/cm²]

More particularly, when the classifier is operated under a fixed condition, coarse particles for which F > R is fulfilled are ejected to the outside of the classifier, while fine particles for which F < R is fulfilled flow to the inside of the classifier, and thereby the pulverized material can be classified into coarse particles and fine particles.

(B) Direction of reflection (α) after the particles have struck against the blades:

In Fig. 10 is also shown the state of the particle striking against the blade. When the direction of reflection (α) after the particles have struck against the blades is directed more outwards than a tangential line, the particles are liable to be ejected to the outside of the classifier, whereas when the direction (c) is directed inwards, the particles are apt to flow into the classifier. It has been known that when a gas flow enters a space between the classifying blades, swirl flows are generated, then fine particles make movement close to the swirl flow, but coarse particles come out of the swirl flow and make movement close to straight movement. Consequently, the direction of reflection after the fine particles have struck against the blades is apt to be directed inwards, whereas that of the coarse particles is apt to be directed outwards, and thereby classification into fine particles and coarse particles can be effected.

Here, let us consider about the inclination angle (mount angle) of the classifying blade (6a). In Fig. 10, representing an inclination angle of the classifying blade (6a) with respect to the direction of the rotary radius r by θ_3, as this inclination angle θ_3 becomes large, a probability of the particles having struck against the classifying blades (6a) jumping out to the outside is increased, and so, fine particles passing through the space between the classifying blades (6a) and coming to the interior would become fine, in other words, an average particle diameter of the classified product would become fine. In this case, the amount of the product is reduced. If the inclination angle θ_3 becomes small, inverse phenomena would arise.

In addition, if an inclination angle of the classifying blade (6a) with respect to the rotary (vertical) axis is represented by θ_2 as seen in Fig. 8, a magnitude of this inclination angle θ_2 would seriously affect the problem whether or not generation of swirls in the proximity of or inside of the classifying blades (6a) is little and a carrier gas can smoothly flow into the classifying blades.

In the third preferred embodiment of the present invention, for the purpose of insuring a stable classifying performance, as described above in Fig. 10 the angle θ_3 formed between the classifying blade (6a) and the rotary radius r is selected to be 30° to 60°. In addition, in Fig. 8 the angle θ_2 formed between the classifying blade (6a) and the rotary axis (the vertical direction) is selected to be 0° to 40°.

Fig. 11 shows a relation between the angle θ_3 and a wearing rate of the classifying blade. According to this diagram, for the angle θ_3 in the proximity of 25° the wearing rate becomes maximum, and it is reduced over the range of the angle θ_3 from 30° to 60°. Fig. 12 shows relations between the angle θ_3 and an amount of product as well as an average particle diameter in the product. As the angle θ_3 becomes large, an amount of product is reduced in accordance with the angle, and an average particle diameter also becomes small. However, in the range of 45° ± 15°, a separating effect would act greatly, and a product having a small average particle diameter can be obtained. In view of the above-described relations, it can be said that a region of the angle θ_3 where operation of a mill having balanced values for a wearing rate of classifying blades, an amount of product and an average particle diameter can be achieved, is 45° ± 15°.

On the other hand, Fig. 13 shows a relation between the angle θ_2 and an average particle diameter in a product. For a given specific gas flow rate (practical gas flow rate/reference gas flow rate) of a carrier gas containing powder, there must be an optimum inclination angle θ_2 for which an amount of coarse particles mixed in fine particles after classification (practical amount/reference amount) becomes minimum, and in the range adapted for practical use, an average particle diameter becomes minimum in the range about 20° ± 20°, that is, in the range of 0° to 40°, and the separating effect becomes large.

The roller mill according to the present invention is constructed as described above, hence a rising carrier gas accompanied by pulverized material enters into an inlet of the rotary blades after it has been rectified in flow by the downwardly convex flow-rectifying cone, thus generation of swirls under the rotary-type classifier is eliminated, flow velocities of a rising carrier gas at the inlet of the rotary blades are made to be uniform, classification of materials to be pulverized by the rotary blades becomes smooth, an efficiency of classification is enhanced, also a sediment of fine powder or the like within the classifier is made to slip and fall due to the slant plate, then it is mixed with the rising carrier gas on the outside of the classifier to be reclassified, and thereby advantages are provided such that a classifying performance and an operational reliability are remarkably improved, and a safety is enhanced in such manner that for instance, autogeneous firing or explosion within a classifier can be prevented.

In addition, according to another aspect of the present invention, hot air passed through a blow-up passageway provided along an outer circumferential portion of a table within a mill main body becomes a rising carrier gas as accompanied by pulverized material ejected to the outer circumference of the table, a part of the rising carrier gas strikes against a baffle plate and is diverted thereby. Upon this diversion coarse particles are primarily classified and made to fall on the table. After the above-mentioned diversion high rising velocity portions and low rising velocity portions are produced in the rising carrier gas within the mill main body, the low rising velocity portions become falling passageways for coarse powder classified by the classifier. Hence the above-mentioned coarse powder can fall smoothly onto the table jointly with the above-described coarse particles, thus a falling performance of coarse powder or the like can be remarkably enhanced, a pressure loss and an amplitude of pressure variations within the mill are greatly reduced, and a pulverizing performance and an operational reliability are greatly improved.

Furthermore, according to still another aspect of the present invention, owing to the fact that an angle formed between a classifying blade of a rotary classifier in a roller mill and a rotary radius is selected to be 30° to 60° and an angle formed between the same classifying blade and a rotary axis to be 0° to 40°, a roller mill incorporating a rotary-type classifier having the optimum configuration can be provided, and thereby classification into fine powder and coarse powder can be carried out efficiently.

While a principle of the present invention has been described above in connection to preferred embodiments of the invention, it is a matter of course that many apparently widely different embodiments of the present invention could be made without departing from the spirit of the present invention.

Claims

1. A roller mill including a table disposed within a mill main body and turned by a vertical drive shaft, a plurality of rollers rotated as pressed against the upper surface of said table to crush material to be pulverized in cooperation with said table, and a rotary-type classifier disposed above said table for classifying pulverized material in a rising carrier gas; characterized in that a downwardly convex flow-rectifying cone is disposed under said rotary-type classifier, and an upwardly convex slant plate for ejecting a sediment with the classifier is disposed above said flow-rectifying cone.

2. A roller mill including a table disposed within a mill main body and turned by a vertical drive shaft, a plurality of rollers rotated as pressed against the upper surface of said table to crush material to be pulverized in cooperation with said table, and a rotary-type classifier disposed above said table for classifying pulverized material in a rising carrier gas; characterized in that a baffle plate for hot air which covers a part of an upper side of a blow-up passageway of hot air provided along the outer circumferential portion of said table as spaced therefrom, is disposed above said blow-up passageway of hot air.

3. A roller mill including a table disposed within a mill main body and turned by a vertical drive shaft, a plurality of rollers rotated as pressed against the upper surface of said table to crush material to be pulverized in cooperation with said table, and a rotary-type classifier disposed above said table for classifying pulverized material in a rising carrier gas; characterized in that said rotary-type classifier comprises a plurality of classifying blades disposed along generating lines of an inversed frusto-conical surface having a vertical axis and rotating about said axis to separate powder in a gas flow into fine powder and coarse powder, an angle formed between said classifying blade and a rotary radius is selected to be 30° to 60°, and an angle formed between said classifying blade and said rotary axis is selected to be 0° to 40°.

4. A roller mill as claimed in Claim 1, characterized in that a baffle plate for hot air which covers a part of an upper side of a blow-up passageway of hot air provided along the outer circumferential portion of said table as spaced therefrom, is disposed above said blow-up passageway of hot air.

5. A roller mill as claimed in Claim 1, characterized in that said rotary-type classifier comprises a plurality of classifying blades disposed along generating lines of an inverse frusto-conical surface having a vertical axis and rotating about said axis to separate powder in a gas flow into fine powder and coarse powder, an angle formed between said classifying blade and a rotary radius is selected to be 30° to 60°, and an angle formed between said classifying blade and said rotary axis is selected to be 0° to 40°.

6. A roller mill as claimed in Claim 2, characterized in that said rotary-type classifier comprises a plurality of classifying blades disposed along generating lines of an inverse frusto-conical surface having a vertical axis and rotating about said axis to separate powder in a gas flow into fine powder and coarse powder, an angle formed between said classifying blade and a rotary radius is selected to be 30° to 60°, and an angle formed between said classifying blade and said rotary axis is selected to be 0° to 40°.

7. A roller mill as claimed in Claim 5, characterized in that a baffle plate for hot air which covers a part of an upper side of a blow-up passageway of hot air provided along the outer circumferential portion of said table as spaced therefrom, is disposed above said blow up passageway of hot air.

Fig. 1

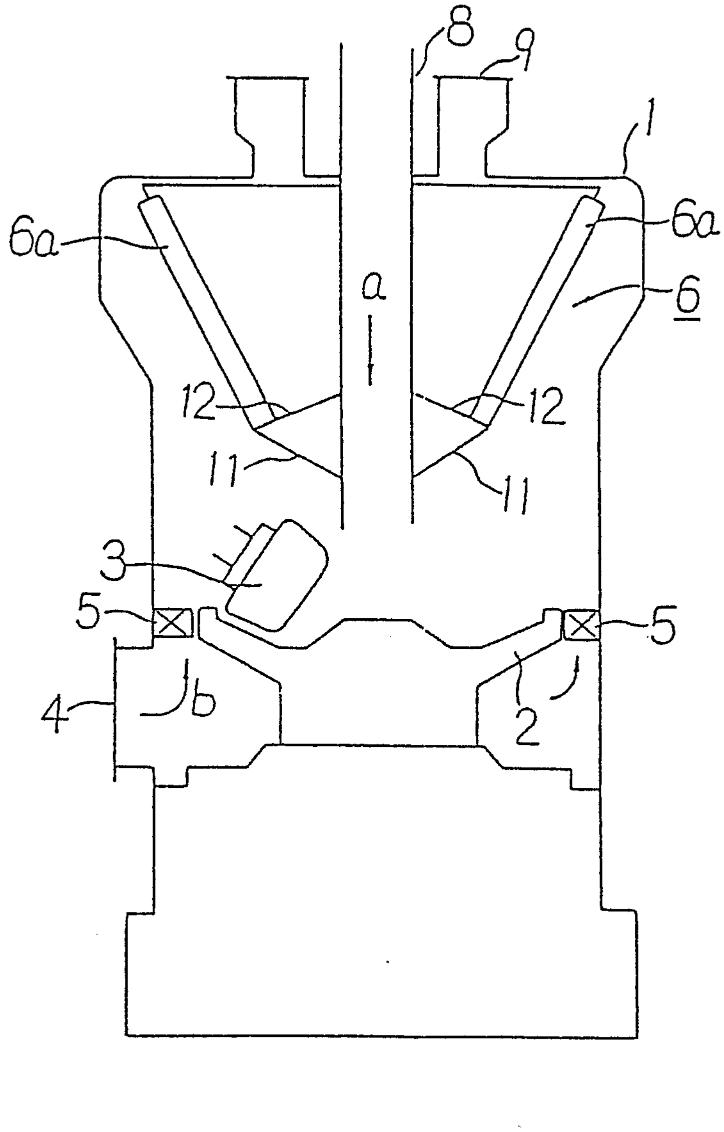
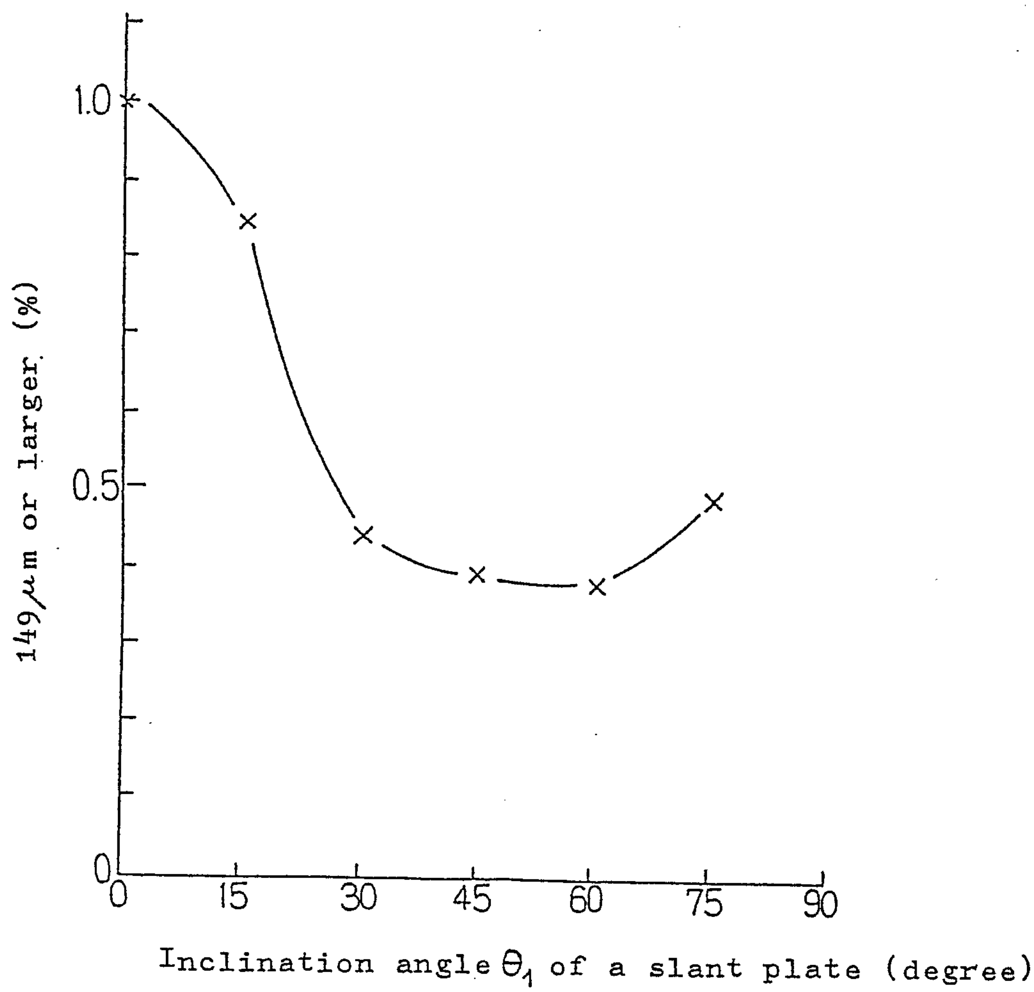


Fig. 2



1.0
0.5
0
149μm or larger (%)
0
15
30
45
60
75
90
Inclination angle θ_1 of a slant plate (degree)

Fig. 3

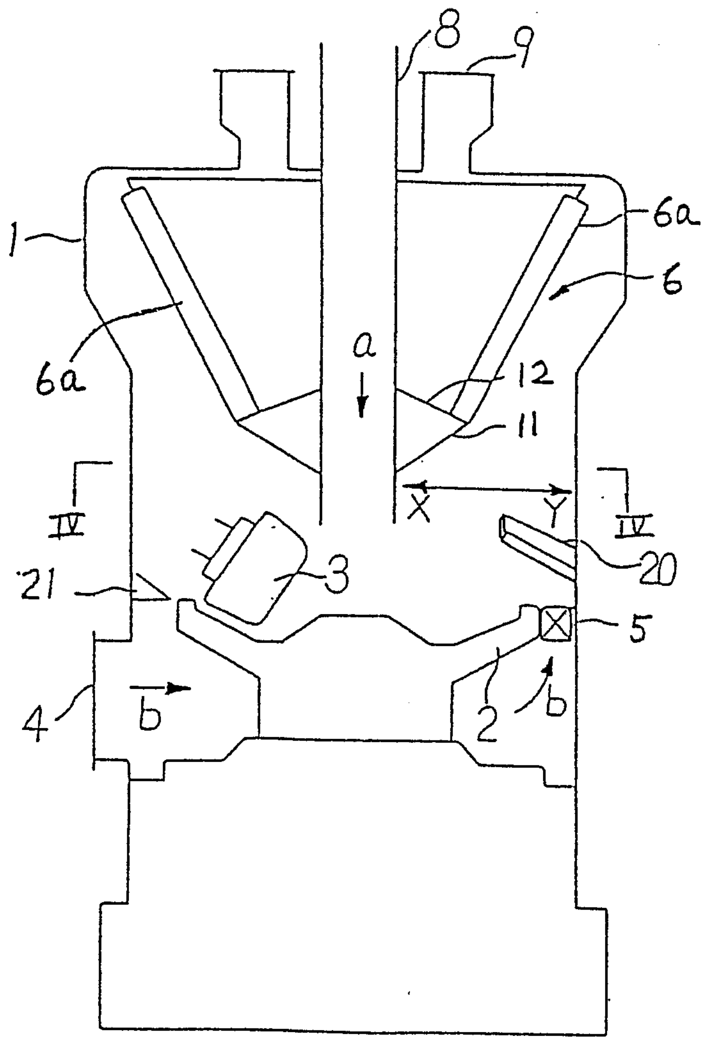


Fig. 4

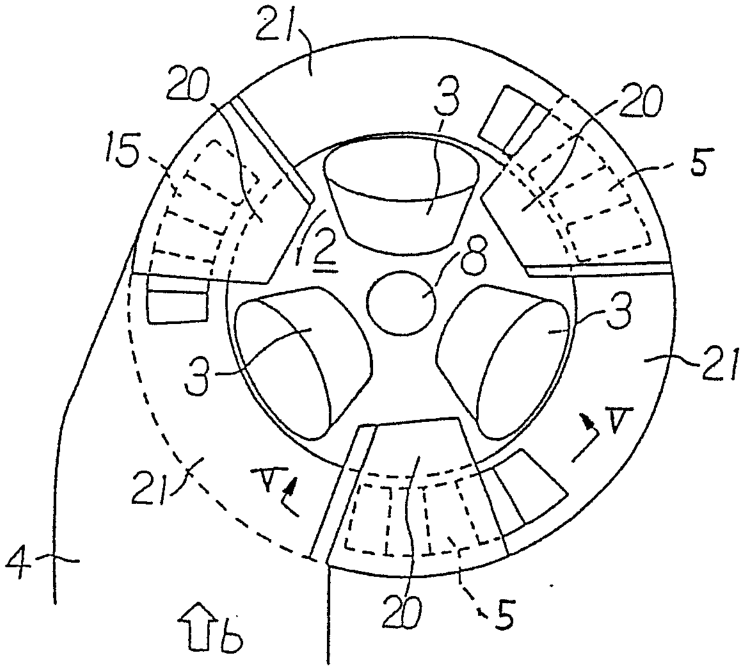


Fig. 5

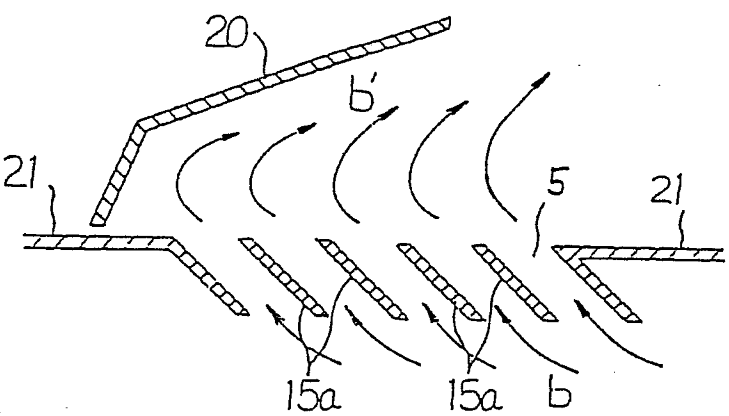


Fig. 6

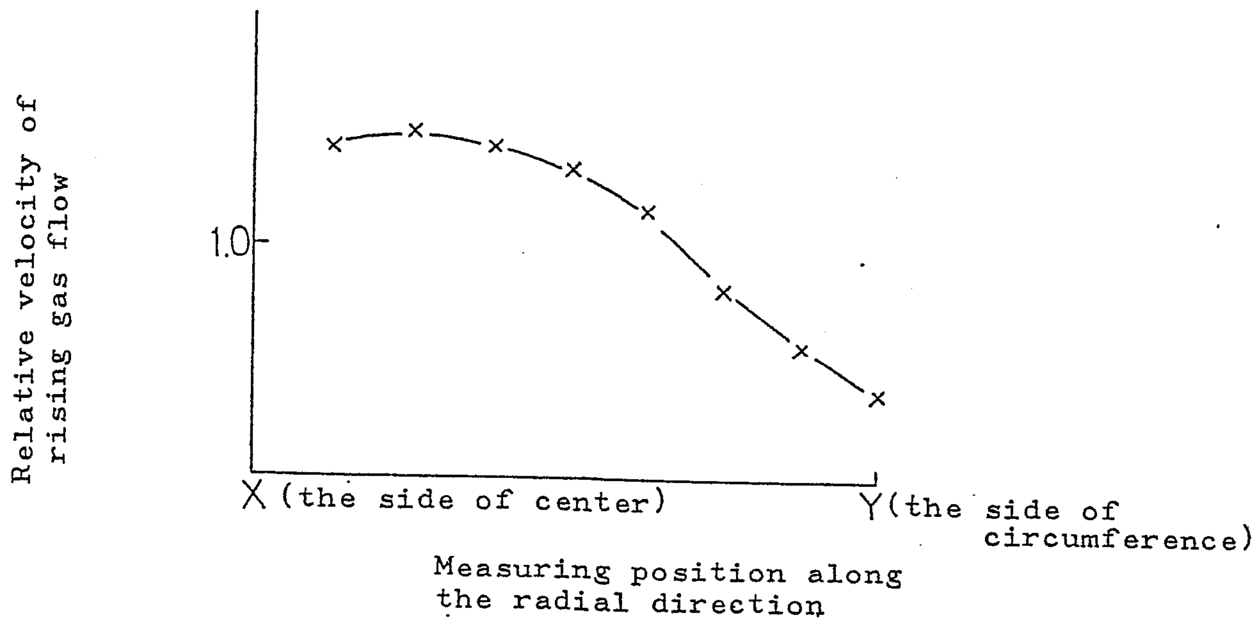

Relative velocity of
rising gas flow
1.0
X (the side of center)
Y (the side of
circumference)
Measuring position along
the radial direction

Fig. 7

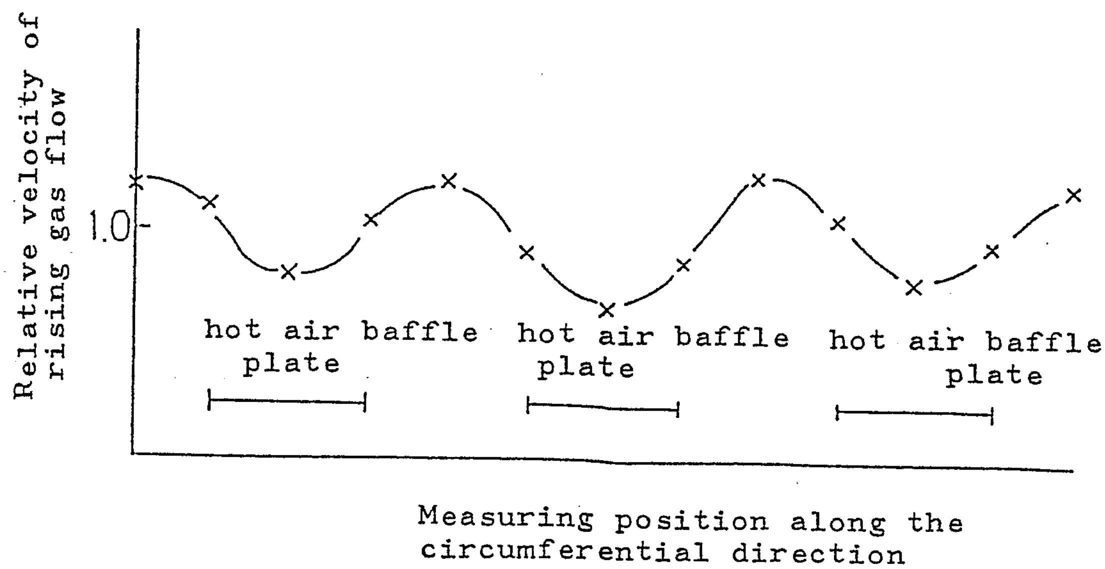

Relative velocity of
rising gas flow
1.0
hot air baffle
plate
hot air baffle
plate
hot air baffle
plate
Measuring position along the
circumferential direction

Fig. 8 (A)

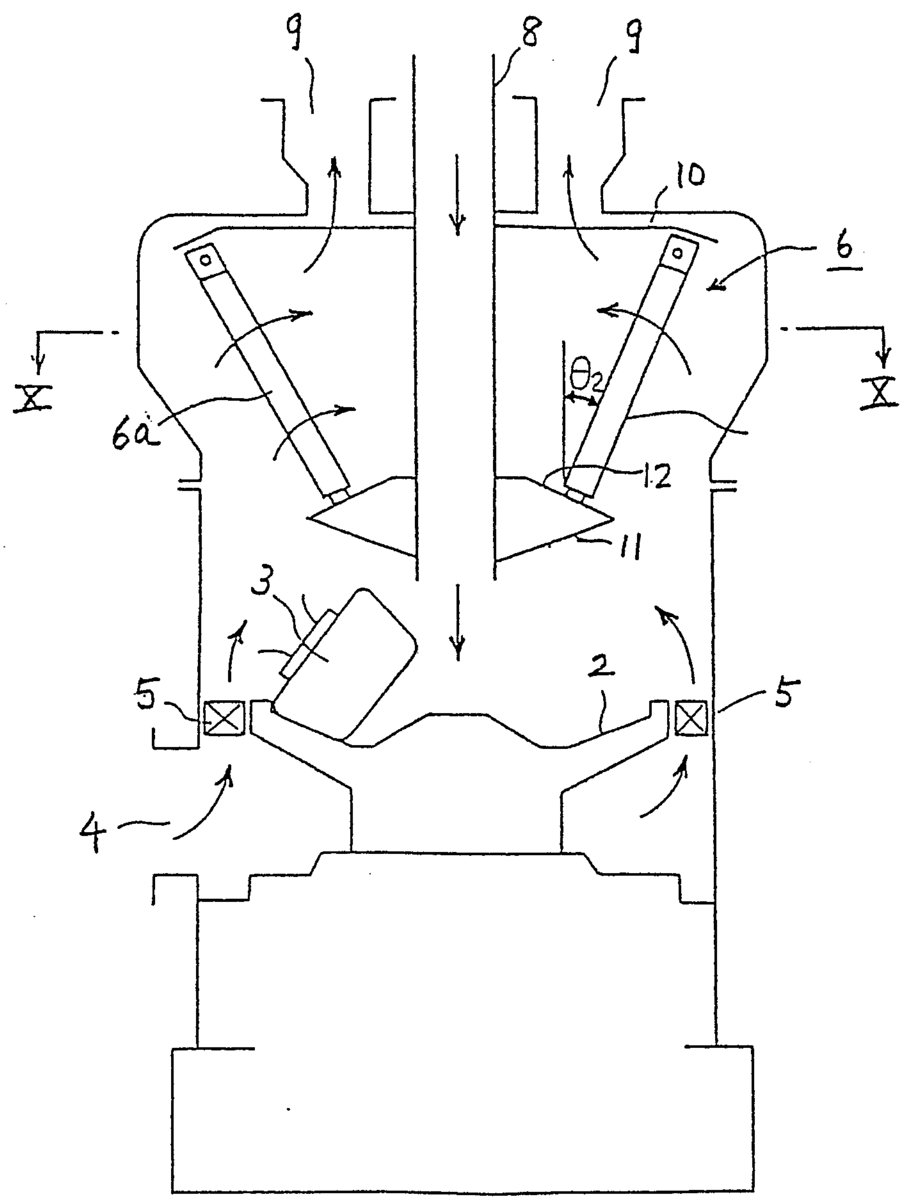


Fig. 8 (B)

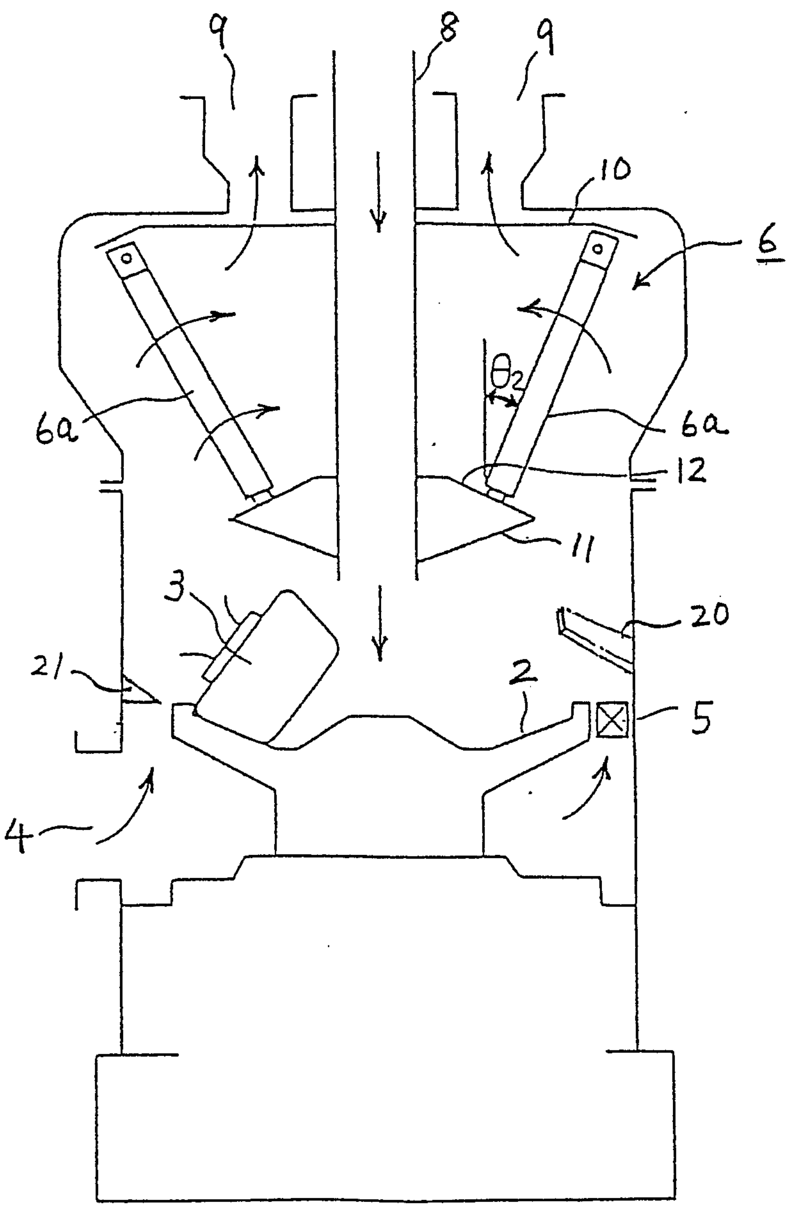


Fig. 9

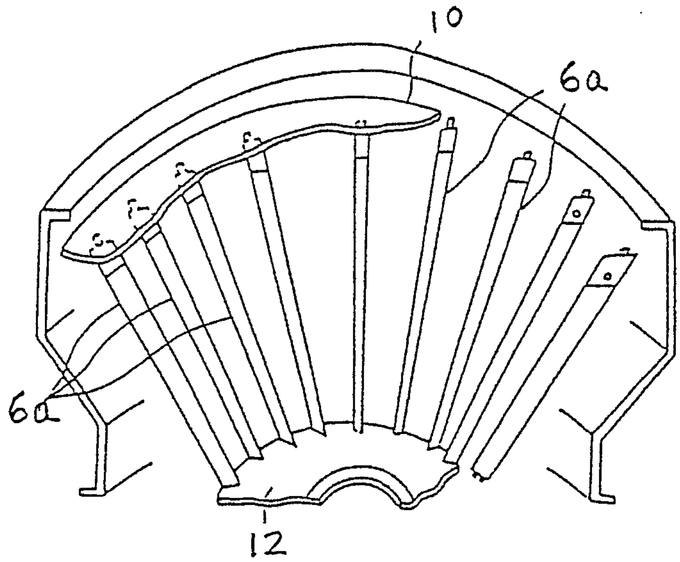

10
6a
6a
12

Fig. 10

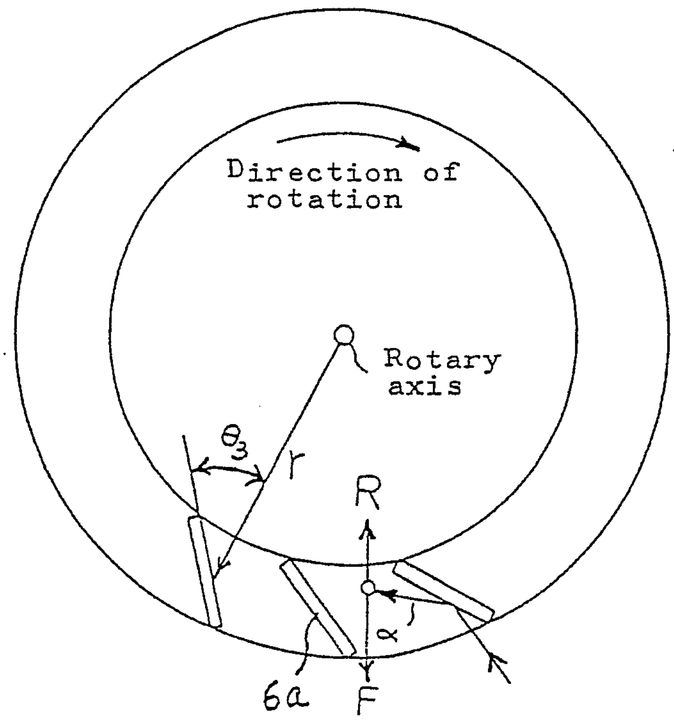

Direction of rotation
Rotary axis
θ_3
r
R
α
6a
F

Fig. 11

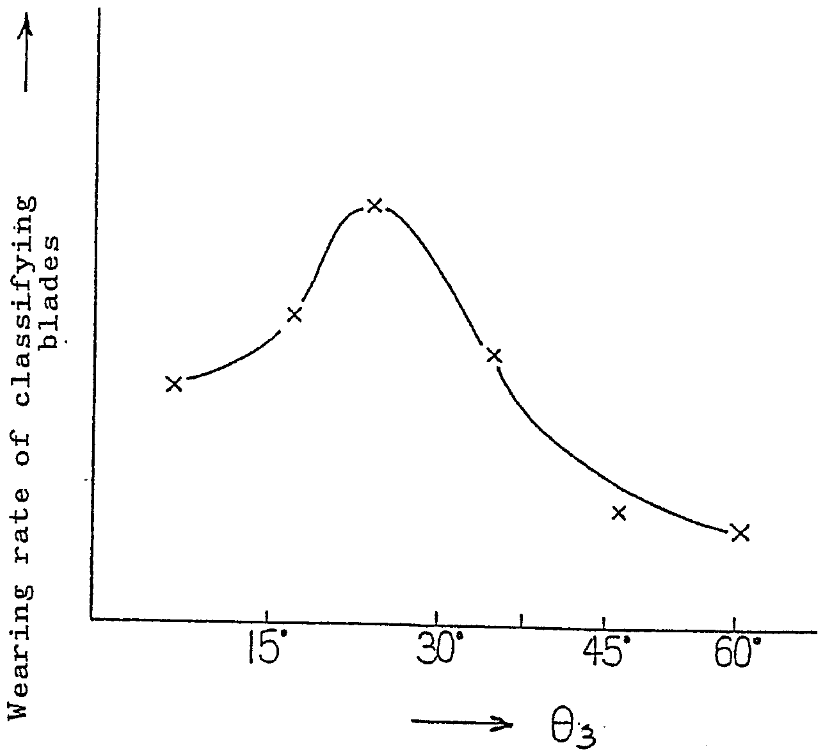

Wearing rate of classifying blades
15°
30°
45°
60°
θ3

Fig. 12

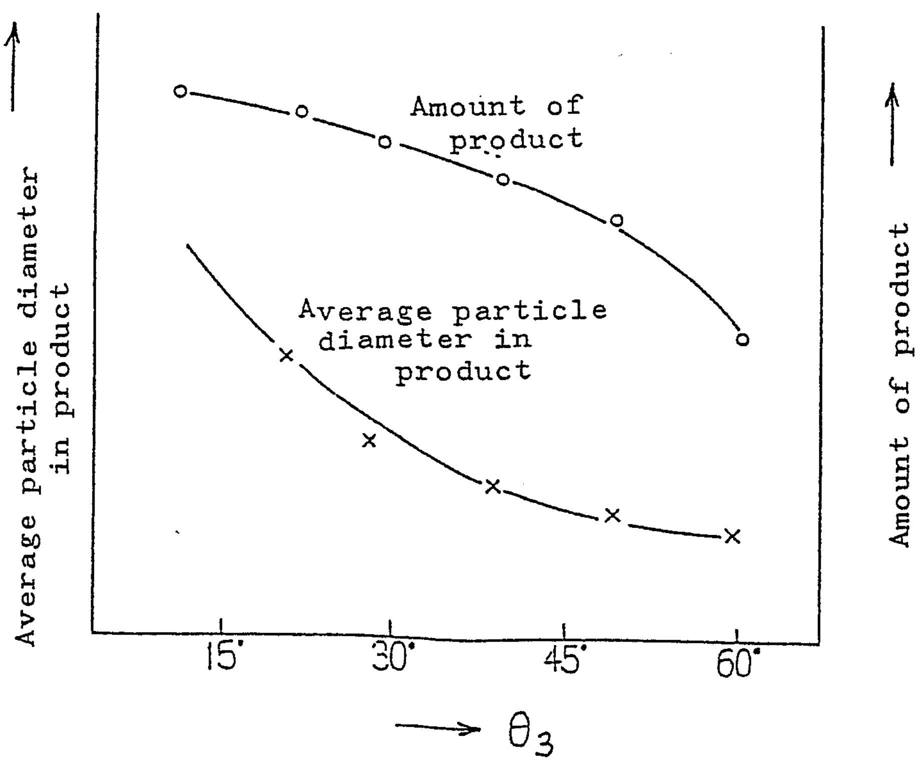

Average particle diameter in product
Amount of product
Amount of product
Average particle diameter in product
15°
30°
45°
60°
θ3

Fig. 13

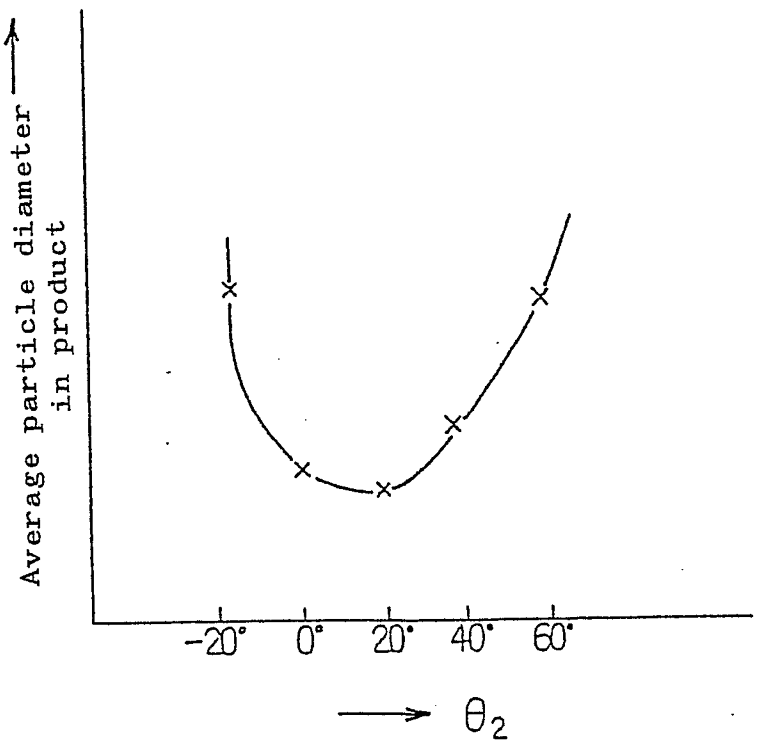
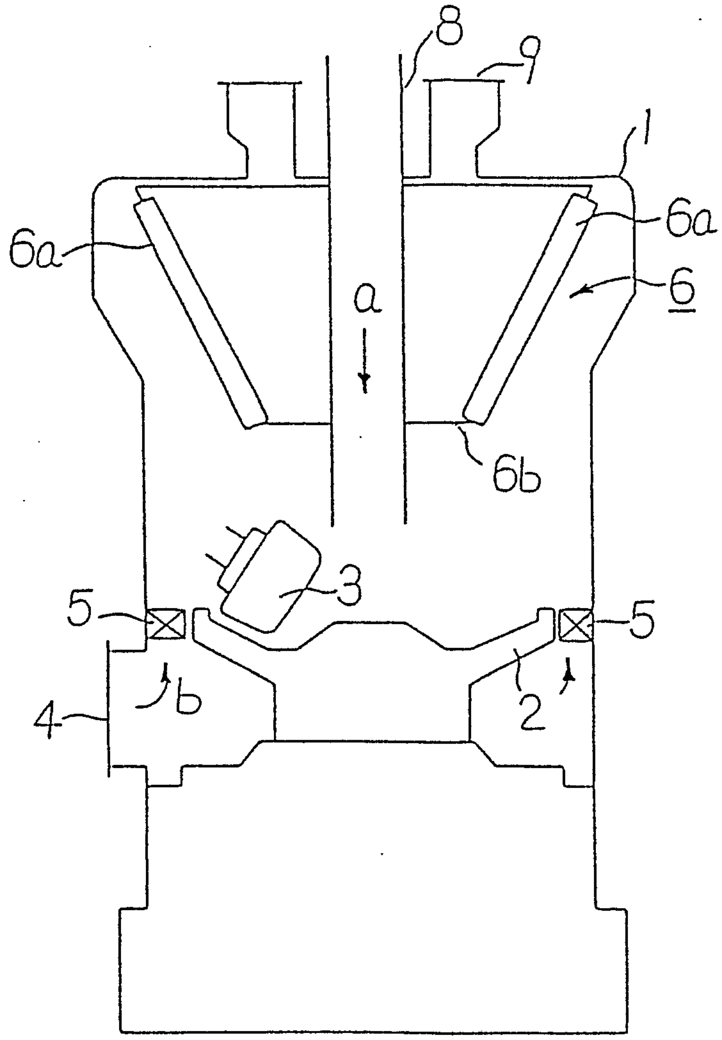


Fig. 14



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88 101 623.2
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It is kindly requested to amend the application papers as stated below:

In Claim 1, line 10, correct "with to --within--.

In page 1, line 19, after "disposed" insert --in opposition--.

In page 11, line 10, after "table," insert --numeral (3) designates a roller,--.

In page 2, the bottom line, correct "[cm/sec]" to --[cm/sec^2]--.

In page 18, line 3, correct "Fig. 4" to --Figs. 4 and 5--.

In page 18, line 4, correct "may be passed" to --may be made to pass--.

In page 21, line 9, correct "and" to --are--.

In page 21, the bottom line, insert between "pulverized" and "would", --on the hot air shut-off plate (21) and the respective baffle plates (20)--.

In page 22, line 10, correct "similary" to --similarly--.

In page 23, Table-3, correct "Syste-A" to --System-A--.

In page 25, line 4, correct "[g/cm^2]" to --[g/cm^3]--.

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