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(71) Applicants *(for all designated States except US)*: **XSTRATA TECHNOLOGY PTY LTD** [AU/AU]; Level 4, 307 Queen Street, Brisbane, Queensland 4000 (AU). **NETZSCH-FEINMAHLTECHNIK GmbH** [DE/DE]; Sedanstrabe 70, D95100 Selb (DE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **RUBENSTEIN, Joshua Beckh** [CA/CA]; 45 Kaymar Drive, Gloucester, ONTario K1J 7C8 (CA). **ANDERSON, Gregory Stephen** [AU/AU]; 18 Pleasant Street, Red Hill, Queensland 4059 (AU).

(74) Agent: **CULLENS**; Level 32, 239 George Street, Brisbane, Queensland 4000 (AU).

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(54) **Title**: ATTRITION MILL

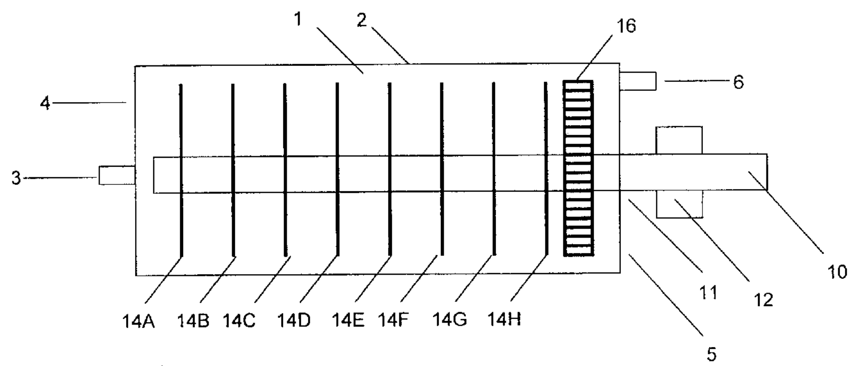

Figure 1

(57) **Abstract**: An attrition mill comprises a grinding chamber having a plurality of grinding elements and an internal classification and separation stage. The mill includes at least one grinding element providing a larger flow path therethrough, when compared to other of the grinding elements. In other embodiments, mill includes at least one grinding element having an open area in the grinding element created to allow a larger flow path as a proportion of the grinding element surface area without such allowance in the range of from 15 % to equal to or less than 100 %.

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ATTRITION MILL

FIELD OF THE INVENTION

The present invention relates to an attrition mill and a method of grinding a material.

BACKGROUND OF THE INVENTION

The term "attrition mill" is herein used to include mills used for fine grinding for example, stirred mills in any configuration such as bead mills, peg mills; wet mills such as colloid mills, fluid energy mills, ultrasonic mills, petite pulverisers, and the like grinders. In general, such mills comprise a grinding chamber and an axial impeller having a series of mainly radially directed grinding elements such as arms or disks, the impeller being rotated by a motor via a suitable drive train. The grinding elements are approximately equally spaced along the impeller by a distance chosen to permit adequate circulation between the opposed faces of adjacent grinding elements and having regard to overall design and capacity of the mill, impeller speed and diameter, grinding element design, mill throughput and other factors.

Such mills are usually provided with grinding media and the source material to be ground is fed to the mill as a slurry. Although the invention is herein described with particular reference to the use of various forms of grinding media added to the mill, it will be understood that the invention may be applied to mills when used for autogenous or semi-autogenous grinding. In the case for example of a stirred mill used for grinding pyrite, arseno-pyrite, or the like, the grinding medium may be spheres, cylinders, polygonal or irregularly shaped grinding elements or may be steel, zircon, alumina, ceramics, silica-sand, slag, or the like. In the case of a bead mill used to grind a sulphide ore (for example galena, pyrite) distributed in a host gangue (for example, shale and/or silica) the gangue may itself be sieved to a suitable size range, for example 1-10 millimeters or 1-4 millimeters, and may be used as a grinding medium. The media size range is dependant on how fine the grinding is required to be. From about 40% to about 95% of the volume capacity of the mill may be occupied by grinding media.

It should be recognized that in the grinding process, grinding media undergoes size reduction as does source material to be ground. Grinding media which is itself ground to a size no longer useful to grind source material is referred to as "spent" grinding media. Grinding media still of sufficient size to grind source material is referred to as "useful" grinding media.

A source material to be ground, for example a primary ore, mineral, concentrate, calcine, reclaimed tailing, or the like, after preliminary size reduction by conventional means (for example to 20-200 microns), is slurried in water and then admitted to the attrition mill through an inlet in the grinding chamber. In the mill, the impeller causes the particles of grinding media to impact with source material, and particles of source material to impact with each other, fracturing the source material to yield fines (for example 0.5-90 microns). It is desirable to separate the coarse material from the fines at the mill outlet so as to retain useful grinding media and unground source material in the mill while permitting the fines and spent grinding media to exit the mill.

In some attrition mills, outlet separation is achieved by means of a perforated or slotted screen at, or adjacent to, the mill exit and having apertures dimensioned to allow passage of spent grinding media and product but not permitting passage of useful grinding media. For example, if it is desired to retain particles of greater than 1 mm in the mill, the outlet screen aperture width would be a maximum of 1 mm so that only particles smaller than 1 mm would exit the mill through the screen. The outlet may in addition comprise a scraper or a separator rotor to reduce screen clogging. The axial spacing between the facing surfaces of the separator rotor and the last downstream grinding element is approximately equal to the spacing between the facing surfaces of all the other pairs of grinding elements.

The design and operation of attrition mills and media selection is highly empirical.

Although various mathematical computer-based models have been proposed, none have yielded satisfactory predictions of mill performance.

In attempting to finely grind a sulphide ore using various grinding media in a high throughput bead mill e.g. having a mill throughput of greater than 10 TPH, it was found that the outlet screen rapidly clogged reducing the throughput to an intolerably low level. Moreover, the rate of wear of the separator rotor and outlet screen rendered operation uneconomic.

United States patent number 5797550, the entire contents of which are incorporated herein by cross reference, describes an attrition mill having improved means for classification and/or separation of coarse particles from fine particles in a slurry. The attrition mill described in this patent comprises a grinding chamber, an axial impeller, a chamber inlet for admitting coarse particles, and a separator comprising a chamber outlet through which fine particles exit from the chamber. The mill is characterised in that a classification between coarse and fine particles is performed in the mill upstream of the separator. By conducting classification between fine and coarse particles upstream from the mill outlet, the maximum size of particles exiting from the mill is substantially independent of the minimum orifice dimensions of the chamber outlet.

Classification may take place in this mill by providing a classifier element defining a first surface in rotation about an axis, a second surface spaced from and facing the first surface so as to define a passage there between, a classifier inlet for admitting slurry to the passage, a first classifier and outlet spaced from the classifier inlet whereby the slurry exits from the passage, a second classifier outlet spaced radially outwardly of the classifier inlet, and means for causing the slurry to flow from the classifier inlet to the first classifier outlet at a predetermined volumetric flow rate. The first surface is spaced sufficiently closely to the second surface and is rotated at sufficient speed so that a majority of the particles in the passage having a mass of less than a predetermined mass remained entrained with slurry flowing into the first classifier outlet and a majority of the particles exceeding a predetermined mass are disentrained and move outwardly from the passage at the second classifier outlet.

The passage may be defined between two members which may be rotated (or counter rotated) independently of the axial impeller and/or of each other.

The attrition mill of this patent may also include a separator stage comprising a separator rotor mounted to the impellor and spaced axially from an endplate to define a radially extending separation passage therebetween, said first classifier outlet admitting slurry to the separation passage at a radially inner region of the separator element, baffle means at or near the separation passage periphery to permit passage of coarse particles travelling outwardly to beyond the separation passage periphery, and a slurry outlet spaced axially from the radially extending separation passage to permit passage of the fine particles out of the mill. The baffle means may be in the form of axial fingers positioned around the periphery of the separator rotor and extending towards the chamber outlet.

The attrition mill described in US patient number 5797550 is commercially available from the present applicant and is sold under the trademark IsaMill™ .

It is known that attrition mills, such as the prior art attrition mills described above, include a plurality of grinding disks mounted to a rotating shaft. These grinding disks typically include a series of openings, such as a plurality of equiangularly spaced openings. During use of prior art attrition mills, the slurry circulates through the apertures in the grinding disks and particles also went between facing surfaces of the grinding disks and flung against other particles, against the shaft between the grinding disks, against the disk surfaces and against the mill walls. The slurry circulates a radial direction between the disks and adjacent to the shaft.

The attrition mill is described in US patent number 5797550 has proven to be technically and commercially successful.

BRIEF DESCRIPTION OF THE INVENTION

It is an object of the present invention to provide an improved attrition mill.

In one aspect, the present invention provides an attrition mill having
- a grinding chamber,
- an inlet positioned at or near an upstream end of the grinding chamber,
- an outlet positioned at or near a downstream end of the grinding chamber,
- a plurality of spaced grinding elements in the grinding chamber, the plurality of spaced grinding elements being rotatably driven,
- the plurality of spaced grinding elements including one or more apertures therethrough or spaces therebetween to enable slurry and grinding media to pass through said one or more apertures or spaces to enable passage of the slurry and the grinding media along the grinding chamber,
- a classification and separation stage located at or near a downstream end of the grinding chamber, the classification and separation stage causing fine particles to be separated from coarse particles and passed to the outlet to thereby remove the fine particles from the grinding chamber whilst causing internal recycle of coarse particles back towards an upstream end of the grinding chamber,
- wherein the mill includes at least one grinding element providing a larger flow path therethrough, when compared to other of the grinding elements.

The present invention arose during studies conducted on attrition mills constructed in accordance with US patent number 5797550. Although the attrition mill described in this US patent has met with considerable commercial success, these mills may be susceptible to significant variations in flow rate through the mill. For example, changing the flow rate of material being fed to the mill can cause significant movement of media within the mill. In some cases, the media can pass into the classification and separation stage, which may result in loss of grinding media from the mill. This is an undesirable outcome.

Although the present inventors do not fully understand the mechanism involved in the present invention, it has been found that providing at least one grinding element that provides a larger flow path therethrough, when compared to other of the grinding elements, acts to suppress or ameliorate excessive movement of media through the mill when variations in flow rate occur by reducing the superficial velocity allowing the media in the slurry to settle.

In some embodiments, the at least one grinding element that provides a larger flow path therethrough is positioned towards a downstream end of the grinding chamber. For example, if the attrition mill includes eight grinding disks, a grinding disk providing a larger flow path therethrough may be positioned at disk 7, in other cases the larger flow path therethrough may be positioned at disk 6, while in other cases the larger flow path therethrough may be positioned at disk 5 (in these embodiments, disk 1 is positioned near the inlet end of the grinding chamber and disk 8 is positioned near the outlet end of the grinding chamber). In other applications, the disk providing the larger flowpath therethrough may be located at other disk positions in the mill.

In one embodiment, the grinding element that provides a large flow path therethrough may comprise a plurality of radially-extending arms. The grinding element may have two to six radially extending arms extending from a central portion. In some embodiments, the grinding element may have four radially extending arm extending from a central point and may have a shape that is similar to the German World War II medal known as an "iron cross". In some embodiments, the grinding element that provides a large flow path therethrough may comprise a cross-like member.

In other embodiments, the grinding element that provides a large flow path therethrough may comprise a grinding disk having apertures therethrough, with the total open area of the apertures being larger than the open area of the apertures in another of the grinding disks in the mill.

The present inventors have also diskovered that the beneficial effects of the present invention, in terms of minimising the suitability of the mill to excessive movement of media arising from changes in the flowrate of material to the mill can be obtained by providing a mill having one, two or more grinding elements having large flow path therethrough, or indeed by providing the mill with all of the grinding elements having a large flow path therethrough. In some applications the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element's surface area without such allowance can be from 15% to equal to or less than 100%. In some applications the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element's surface area without such allowance can be from 20% to equal to or less than 100%. In some applications the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element's surface area without such allowance can be from 25% to equal to or less than 100%. In some applications the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element's surface area without such allowance can be from 30% to equal to or less than 100%.

Accordingly, in a second aspect, the present invention provides an attrition mill having
- a grinding chamber,
- an inlet positioned at or near an upstream end of the grinding chamber,
- an outlet positioned at or near a downstream end of the grinding chamber,
- a plurality of spaced grinding elements in the grinding chamber, the plurality of spaced grinding elements being rotatably driven,
- the plurality of spaced grinding elements including one or more apertures therethrough or spaces therebetween to enable slurry and grinding media to pass through said one or more apertures or spaces to enable passage of the slurry and the grinding media along the grinding chamber,
- a classification and separation stage located at or near a downstream end of the grinding chamber, the classification and separation stage causing fine particles to be separated from coarse particles and passed to the outlet to thereby remove the fine particles from

the grinding chamber whilst causing internal recycle of coarse particles back towards an upstream end of the grinding chamber,

- wherein the mill includes at least one grinding element having an open area in the grinding element created to allow a larger flow path as a proportion of the grinding elenemt's surface area without such allowance in the range of from 15% to equal to or less than 100%.

In this specification, the percentage open area is calculated as the surface area of the apertures (equivalent to the total size of the apertures) and this is then divided by the difference of the full surface area of the disk without the apertures, minus the area of the central hub.

In the example shown in Fig 8, the calculation is based on a disk used for an M20 IsaMill™ and is calculated as:

Area of Full Disk = 25434mm^2
Area of Hub = 3957mm^2
Area Apertures = 13501mm^2

$$\% \text{ Open Area} = \frac{\text{Area of Aperatures}}{\text{Area of Full Disk} - \text{Area of Hub}} \times 100\%$$

$$\% \text{ Open Area} = \frac{13501 \times 100\%}{25434 - 3957}$$

% Open Area = 63 %.

In figure 8, the disk has an outer diameter of 180mm, the central aperture has a diameter of 71mm and the openings have a radial length of 45mm.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a schematic diagram, partly in cross-section, of an attrition mill in accordance with an embodiment of the present invention;

Figure 2 shows a front view of a conventional grinding disk suitable for use in an embodiment of the present invention;

Figure 3 shows a schematic diagram of a circulation pattern of media and slurry within the attrition mill in the vicinity of the grinding disks;

Figure 4 shows a front view of a grinding disk in the form of an iron cross suitable for use in an embodiment of the present invention;

Figure 5 shows a front view of another grinding disk having a larger flow area therethrough suitable for use in an embodiment of the present invention;

Figure 6 shows a front view of yet another grinding disk having a larger flow area therethrough suitable for use in an embodiment of the present invention;

Figure 7 shows a front view of another grinding disk having a larger flow area therethrough suitable for use in an embodiment of the present invention; and

Figure 8 shows a front view of a grinding disk used in the example of calculating the open area, as given above.

DETAILED DESCRIPTION OF THE DRAWINGS

It will be appreciated that the drawings have been provided for the purposes of illustrating preferred embodiments of the present invention. Therefore, it will be understood that the present invention should not be considered to be limited side to the features as shown in the attached drawings.

With reference to FIG. 1 there is shown schematically a prior art attrition mill comprising a grinding chamber 1 defined by a generally cylindrical side wall 2, an inlet end wall 4 and a diskharge end wall 5. Chamber 1 is provided with an inlet port 3 and an outlet pipe 6. Chamber 1 is mounted to foundations by means not illustrated. An axial shaft 9 extends through inlet diskharge end wall 5 at a sealing device 11. Shaft 9 is driven by a drive train (not illustrated) and is supported by bearing 12. Internally of chamber 1, shaft 9 is fitted with a series of radially directed grinding disks 14 each of which when viewed in plan is seen to be pierced by equiangularly-spaced openings 15 (shown in FIG. 2). In the present example grinding disks 14 are keyed to shaft 9 and each grinding disk 14 is equidistance spaced from adjacent grinding disks 14. As can be seen from figure 1, the mill is provided with eight grinding disks, respectively referred to by reference numerals 14A, 14B,...14H.

With reference to FIG. 3 there are shown schematic flow patterns (indicated by arrowed lines) believed to occur in and around adjacent grinding disks 14 of the mill of FIG. 1. Slurry circulates through apertures 15 in grinding disks 14 and particles also enter between facing surfaces of grinding disks 14 and are flung against other particles, against the shaft between grinding disks, against the disk surfaces, and against the mill walls. Slurry circulates in a radial direction between the disks and preferably to adjacent shaft 10. As a result, attrition of the particulate matter fed to the attrition mill occurs, resulting in a size reduction of the particulate material. The mill will also be typically provided with a grinding media to facilitate size reduction. The grinding media may comprise steel balls, ceramic particles, sand or indeed any other grinding media known to be suitable to a person skilled in the art. If the mill is an autogenous mill, a separate grinding media will not be present.

The mill shown in figure 1 also includes a classification and separation stage 16 which provides an internal classification of particles. The classification and separation stage 16 may be as described in United States patent number 5797550, the entire contents of which are herein incorporated by cross reference. The classification and separation stage 16 classifies and separates relatively coarse particles in the mill from relatively fine particles. The fine particles are sent to the mill outlet and exit the mill whilst the coarse particles are effectively recycled internally in the mill and move back towards the inlet end of the mill, so that they may be subject to further grinding or attrition.

The mill shown schematically in figure 1 is commercially available from the present applicant and is sold under the trademark IsaMill™ . Persons skilled in the art of attrition or grinding will readily understand how such a mill is constructed and operates.

In presently available IsaMills™ , each of the grinding disks 14A to 14H are essentially identical to each other. However, the present inventors have found that attrition mills having this configuration may be susceptible to significant movement of the media within the mill if the flowrate of material being fed to the mill varies. To overcome this difficulty, the present inventors have found that replacing one or more of the grinding disks with grinding disks having a larger flow area therethrough (than grinding disks presently being used in such mills) achieves a reduction in movement of media through the mill.

Figures 4 shows a schematic diagram of one possible replacement grinding disk suitable for use in an embodiment of the present invention. The grinding disk 20 in figure 4 includes a central aperture 10 that is similar to the disk shown in figure 2. This aperture allows the disk 20 to be mounted onto the shaft 9. The disk includes a central portion 21 that surrounds the central aperture 10. The disk has four arms 22, 23, 24 and 25 extending radially outwardly from the central portion 21. The disk 20 shown in figure 4 has a flow path therethrough that is defined by the spaces 26, 27, 28 and 29 between the adjacent arms 22 to 25. As can be seen by comparing figure 4 with figure 2, the spaces provide a much larger combined area than the open area provided by the apertures 15 in figure 2.

Figure 5 shows a schematic view of another disk that may be used in embodiments of the present invention. The disk 30 shown in figure 5 includes a central aperture 10. However, this disk also includes a plurality of apertures 31, 32, 33, etc. The disk 30 shown in figure 5 has more apertures than the disk shown in figure 2. Furthermore, the apertures of the disk 30 in figure 5 are larger than the apertures 15 in the disk 14 of figure 2. Therefore, the disk 30 of figure 5 provides a disk having a larger flow path for slurry therethrough when compared with the disk 14 shown in figure 2.

Figure 6 shows a schematic view of another disk suitable for use in an embodiment of the present invention. In the embodiment shown in figure 6, the disk 40 includes a plurality of apertures 41, 42, 43, etc. Each of these apertures 41, 42, 43 is largely identical to the apertures 15 of the disk 14 shown in figure 2. However, the disk 40 shown in figure 6 has a larger number of apertures than the disk 14 shown in figure 2.

In embodiments of the present invention, the disk that provides a larger flow path therethrough may be placed at the position of disk 14G, as shown in figure 1. In other embodiments the disk that provides a larger flow path therethrough may be placed in any other position from disk 14A to 14H. Alternatively, two or more of the disks shown in figure 1 may be replaced by disks as shown in any of figures 4 to 6. Indeed, in some embodiments, all of the disks 14A to 14H shown in figure 1 may be replaced with the disks as shown in any one of figures 4 to 6.

Figure 7 shows a a schematic diagram that is similar to that shown in Figure 4 but with 5 arms instead of 4 arms. The grinding disk 120 in figure 7 includes a central aperture 110 that is similar to the disk shown in figure 2. This aperture allows the disk 120 to be mounted onto the shaft 9. The disk includes a central portion 121 that surrounds the central aperture 110. The disk has five arms 122, 123, 124, 125 and 126 extending radially outwardly from the central portion 121. The disk 120 shown in figure 7 has a flow path therethrough that is defined by the spaces 127, 128, 129, 130 and 131 between the adjacent arms 122 to 126. As can be seen by comparing figure 7 with figure 2, the spaces provide a much larger combined area than the open area provided by the apertures 15 in figure 2.

Those skilled in the art will appreciate that the present invention may be susceptible to variations and modifications other than those specifically described. It will be understood that the present invention encompasses all such variations and modifications that fall within its spirit and scope.

CLAIMS

1. An attrition mill having
- a grinding chamber,
- an inlet positioned at or near an upstream end of the grinding chamber,
- an outlet positioned at or near a downstream end of the grinding chamber,
- a plurality of spaced grinding elements in the grinding chamber, the plurality of spaced grinding elements being rotatably driven,
- the plurality of spaced grinding elements including one or more apertures therethrough or spaces therebetween to enable slurry and grinding media to pass through said one or more apertures or spaces to enable passage of the slurry and the grinding media along the grinding chamber,
- a classification and separation stage located at or near a downstream end of the grinding chamber, the classification and separation stage causing fine particles to be separated from coarse particles and passed to the outlet to thereby remove the fine particles from the grinding chamber whilst causing internal recycle of coarse particles back towards an upstream end of the grinding chamber,
- wherein the mill includes at least one grinding element providing a larger flow path therethrough, when compared to other of the grinding elements.

2. An attrition mill as claimed in claim 1 wherein the grinding element that provides a larger flow path therethrough comprises a plurality of radially-extending arms.

3. An attrition mill as claimed in claim 2 wherein the grinding element has two to six radially extending arms extending from a central portion.

4. An attrition mill as claimed in claim 3 wherein the grinding element has four radially extending arm extending from a central point.

5. An attrition mill as claimed in claim 4 wherein the grinding element has a shape that is similar to the German World War II medal known as an "iron cross", or the the

grinding element that provides a larger flow path therethrough comprises a cross-like member.

6. An attrition mill as claimed in claim 1 wherein the grinding element that provides a larger flow path therethrough comprises a grinding disk having apertures therethrough, with the total open area of the apertures being larger than the open area of apertures in another of the grinding disks in the mill having a smaller flow path therethrough.

7. An attrition mill as claimed in any one of the preceding claims wherein the at least one grinding element that provides a larger flow path therethrough is positioned towards a downstream end of the grinding chamber.

8. An attrition mill as claimed in claim 7 wherein the the attrition mill includes eight grinding disks and a grinding disk providing a larger flow path therethrough may be positioned at disk 7 or at disk 6 or at disk 5, wherein disk 1 is positioned near the inlet end of the grinding chamber and disk 8 is positioned near the outlet end of the grinding chamber.

9. An attrition mill as claimed in any one of the preceding claims wherein the mill comprises two or more grinding elements having large flow path therethrough.

10. An attrition mill having

- a grinding chamber,
- an inlet positioned at or near an upstream end of the grinding chamber,
- an outlet positioned at or near a downstream end of the grinding chamber,
- a plurality of spaced grinding elements in the grinding chamber, the plurality of spaced grinding elements being rotatably driven,
- the plurality of spaced grinding elements including one or more apertures therethrough or spaces therebetween to enable slurry and grinding media to pass through said one or more apertures or spaces to enable passage of the slurry and the grinding media along the grinding chamber,

- a classification and separation stage located at or near a downstream end of the grinding chamber, the classification and separation stage causing fine particles to be separated from coarse particles and passed to the outlet to thereby remove the fine particles from the grinding chamber whilst causing internal recycle of coarse particles back towards an upstream end of the grinding chamber,
- wherein the mill includes at least one grinding element having an open area in the grinding element created to allow a larger flow path as a proportion of the grinding element surface area without such allowance in the range of from 15% to equal to or less than 100%.

11. An attrition mill as claimed in claim 10 wherein the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element's surface area without such allowance is from 20% to equal to or less than 100%.

12. An attrition mill as claimed in claim 10 wherein the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element's surface area without such allowance is from 25% to equal to or less than 100%.

13. An attrition mill as claimed in claim 10 wherein the open area in the grinding element created to allow a larger flow path as a proportion of the grinding element 's surface area without such allowance is from 30% to equal to or less than 100%.

14. An attrition mill as claimed in any one of claims 10 to 13 wherein the mill includes two or more grinding elements having an open area in the grinding element created to allow a larger flow path as a proportion of the disk's surface area without such allowance in the range of from 15% to equal to or less than 100%.

15. An attrition mill as claimed in claim 14 wherein all of the grinding elements in the mill have an open area in the grinding element created to allow a larger flow path as a proportion of the disk's surface area without such allowance in the range of from 15% to equal to or less than 100%.

16. An attrition mill as claimed in any one of caims 10 to 15 wherein the percentage open area is calculated from the equation:

$$\% \text{ Open Area} = \frac{\text{Area of Aperatures}}{\text{Area of Full Disk} - \text{Area of Hub}} \times 100\%$$

17. An attrition mill as claimed in any one of the preceding claims comprising a horizontal shaft attrition mill.

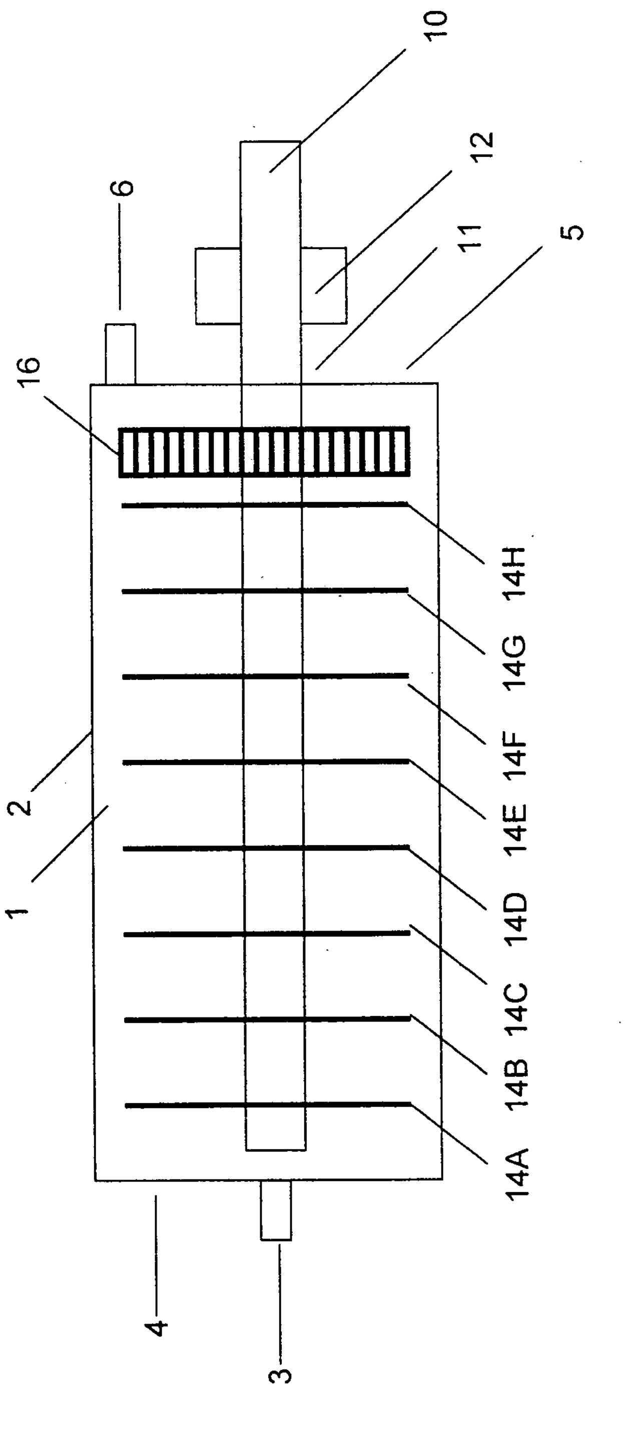

Figure 1

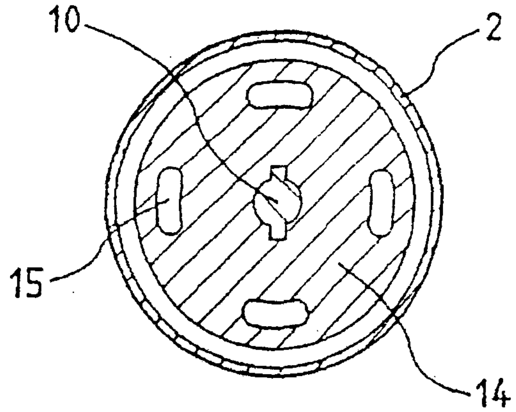

FIG.2

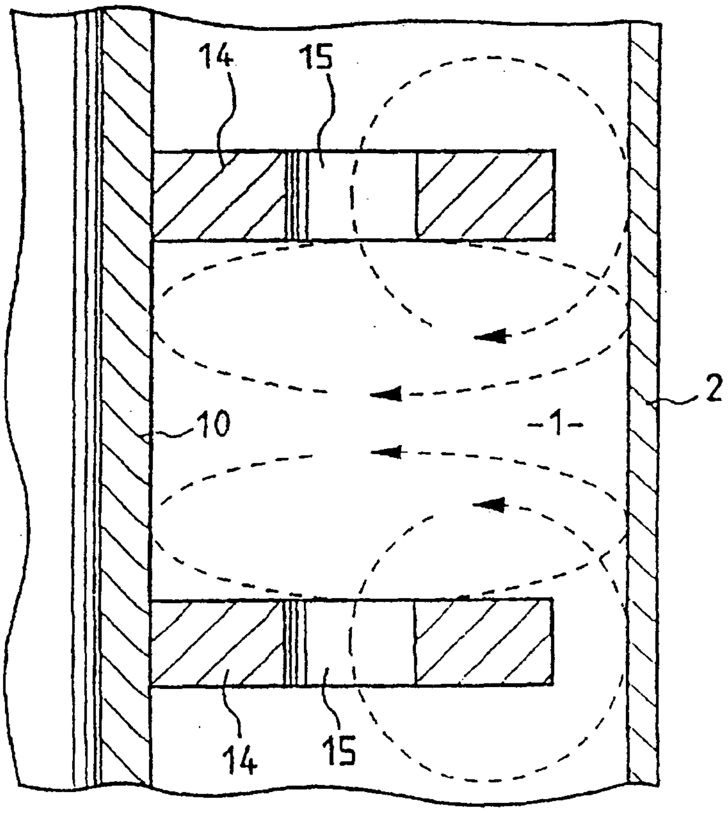

FIG.3

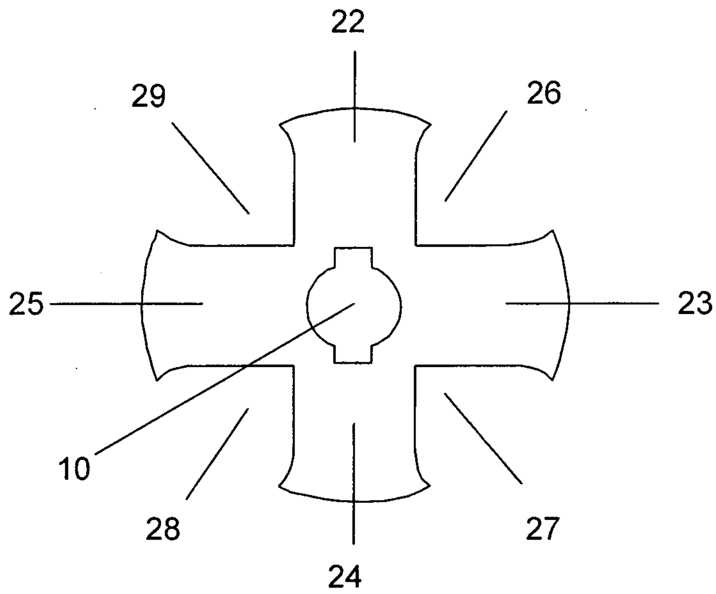

Figure 4

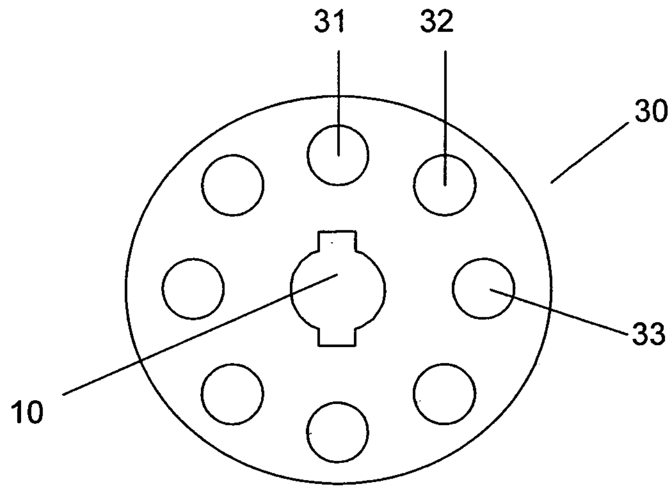

Figure 5

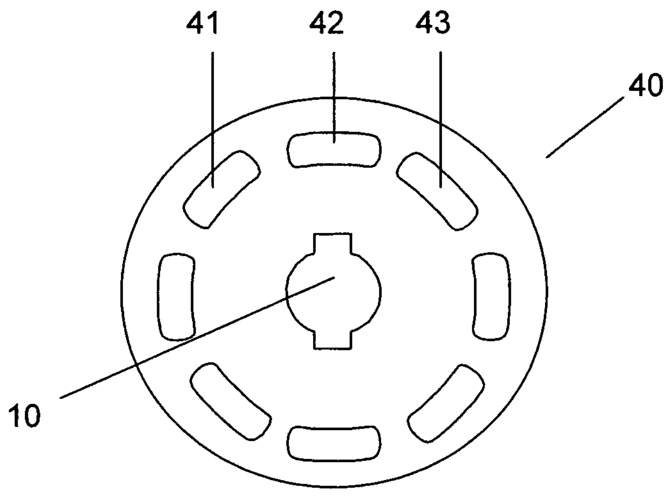

Figure 6

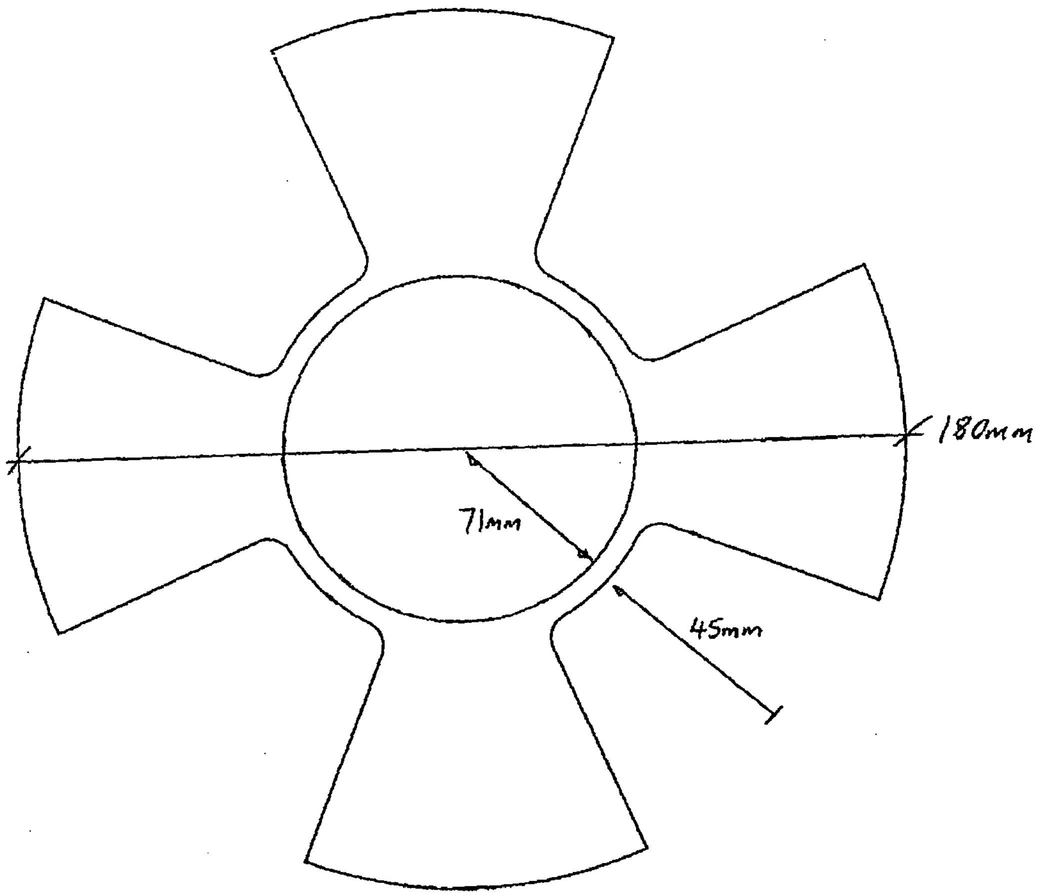

FIGURE 8

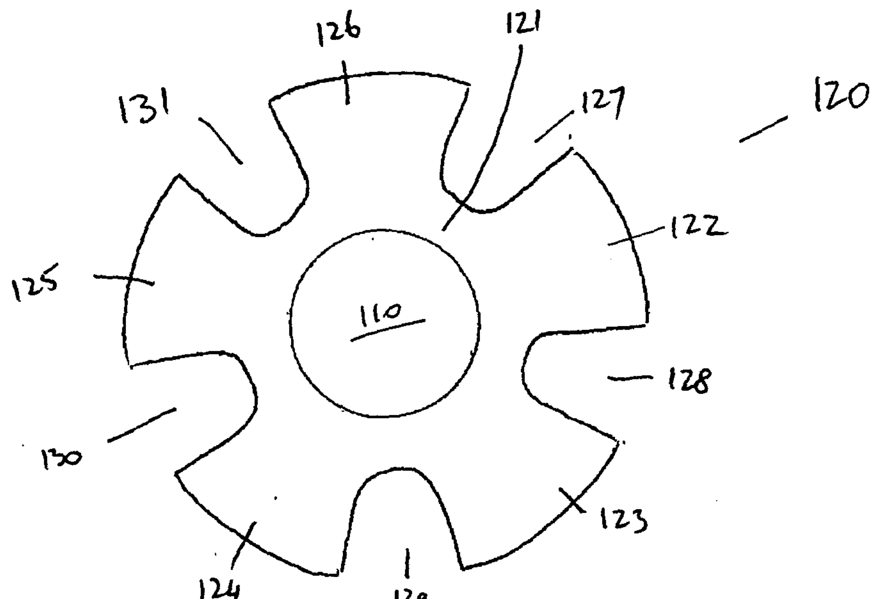

FIGURE 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/AU2009/001644

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.

B02C 17/14 (2006.01) ***B02C 17/20*** (2006.01) ***B02C 23/16*** (2006.01)
B02C 13/10 (2006.01) ***B02C 23/10*** (2006.01) ***B02C 23/18*** (2006.01)
B02C 17/16 (2006.01) ***B02C 23/14*** (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPOQUE (EPODOC and WPI): EC/IC marks and Keywords (B02C17/14, B02C17/16, B02C17/20, B02C23/10, B02C23/16, B02C23/18, B02C23/14, B02C13/10) and (ROTAT+, AXIAL+, SHAFT+, SEPARAT+, CLASSIF+, SORT+, RECYCL+, LOOP+, APERTUR+, SPACE, OPENING+, SLOT+, SLIT+, GAP+, ENLARG+, WID+, DISC,DISK, ARM, IMPELLER)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5333804 A (LIEBERT) 2 August 1994 column 1: lines 2-10, column 3: lines27-36 and figs. 1, 5 and 6	1, 6, 7, 10-17
P, A	WO 2009/024159 A1 (BÜHLER AG et al.) 26 February 2009	
A	US 5597126 A (FROMMHERZ et al.) 28 January 1997	
A	DE 1183344 B (RUTKOWSKI DIPL-CHEM DR RUDI et al.) 10 December 1964	

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

* Special categories of cited documents:

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

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

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"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 when the document is taken alone

"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

Date of the actual completion of the international search	Date of mailing of the international search report
02 February 2010	11 FEB 2010
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. +61 2 6283 7999	Authorized officer **VEENA BHAT** AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No : +61 2 6283 7963

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/AU2009/001644

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member			
US	5333804	DE	4425832	JP	7060147
WO	2009024159	NONE			
US	5597126	EP	0627262	JP	7008823
DE	1183344	NONE			

Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.

END OF ANNEX