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(54) **Wet grinding system.**

(57) There is disclosed a grinding system. Based on a vertical shaft impactor, a system is disclosed which provides improved results by allowing materials to be ground in a wet form. The grinding system includes supply lines and inlets which allow material to be supplied in such a form.

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This invention relates to a grinding system, and specifically to an apparatus which may be used for grinding wet material.

There are a wide variety of situations in which it is necessary to grind materials, in order to reduce particle sizes. One type of grinding apparatus is a vertical shaft impactor, or VSI, such as a Barmac Rotopactor or Duopator (Trade Marks). These machines have a rotor, which rotates about a vertical axis, and which causes the feed material to be flung outwardly towards an impact surface. Vertical shaft impactors with two inlets are also known, in which feed material supplied to the second inlet cascades past the rotor through the material being flung outwardly from the rotor.

The machines described above are used extensively for autogenous grinding of dry feed material such as rocks and ores, but there are many situations in which the feed material is not dry, and it has previously been thought that such materials are unsuitable for grinding in this way. Moreover, it has been found that there may be surprising advantages if the feed materials are processed in a wet condition. The present invention therefore seeks to provide an apparatus which allows grinding to be carried out in a wet state. Furthermore by grinding minerals or materials in the presence of solvents or chemical reagents it may be possible to clean environmentally noxious materials or release bound minerals from their parent materials in a more efficient and economical manner.

Embodiments of the present invention further seek to provide an apparatus for the treatment of oil- or water-based cuttings, such as the by-products of drilling for oil, gas and other subterranean fluids. Other materials associated with these spheres of activity may be contaminated with oil or other materials used in drilling operations. The cuttings may also be in the form of Low Specific Activity scales, which are produced during some drilling activities.

According to the present invention, there is provided a grinding system including a vertical shaft impactor grinding apparatus, the grinding apparatus comprising:

a feed hopper defining a first inlet for feed material;

a rotor; and

an outlet;

the rotor being mounted such that it can rotate in the apparatus; and

the feed hopper being connected to a feed tube which directs all of the inlet feed material from the first inlet to the rotor such that it is flung outwardly by the rotor into a grinding region, and the system further including:

a classifier, for separating oversized ground material from material removed from the grinding apparatus;

a first supply line, suitable for transporting ground material within a liquid from the outlet to the classifier; and

a second supply line, suitable for returning separated oversized ground material within a liquid from the classifier to the grinding apparatus.

References herein to "classifying" a material or to a "classifier" include any method or device for separating particles on the basis of their sizes, including the use of a vibrating screen.

For a better understanding of the present invention, and to show how it may be brought into effect, reference will now be made, by way of example, to the accompanying drawings in which:-

Figure 1 is a schematic diagram illustrating a largely conventional grinding apparatus;

Figure 2 is a schematic diagram illustrating a system in accordance with a first embodiment of the present invention;

Figure 3 is a schematic diagram illustrating a second system in accordance with the present invention;

Figure 4 is a schematic cross-section through a vertical shaft impactor for use as part of a system in accordance with the invention;

Figure 5 is a cross-section through an alternative vertical shaft impactor for use as part of a system in accordance with the invention; and

Figure 6 is a partial section through the device shown in Figure 5, along line VI-VI.

Figure 1 shows a grinding system based on one type of vertical shaft impactor or VSI 11. The VSI 11 has an internal rotor, and feed material which enters the device is flung outwardly towards an impact surface at which crushing and grinding takes place. Feed material, such as rock or ore, is supplied to the VSI 11 along a suitable conveying device 12 from a feed hopper 13, or other source of supply.

Ground material from the VSI 11 leaves at the bottom of the device and falls on to a screen 14, which acts as a classifier. Fine material passes through the screen and is collected on a conveyor 15, by which it can be transported for further processing or disposal. Oversized particles do not pass through the screen 14, and are returned on a conveyor 16 to the conveyor 12, by which they are returned to the inlet of the VSI 11 so that they can be further reduced.

This system is suitable for dry or semi dry grinding of a large number of materials. However, there are other grinding applications in which this system may not be appropriate. For example, there are situations where it may be desirable to carry out grinding in the presence of large quantities of water, or other fluids. One example of this is in the grinding of Low Specific Activity (LSA) scales.

These are naturally occurring rock substances which emit low level radioactivity. The scales are produced by the agglomeration of particles which are produced, for example during drilling for oil through certain rock formations, such as those occurring in the North Sea. The levels of radioactivity are low enough that, if the scales are ground to a small particle size, they can be safely disposed of. However, the grinding of the scales is difficult, because if this were to be done dry there would be a danger that fine particles of dust, with unacceptable levels of radioactivity, would be produced, and may become airborne. However, the grinding of LSA scales in a wet state ensures that this dust is not produced. The present invention discloses a system for grinding these materials, and any other materials which are more easily handled or processed in a wet form, in a way that allows the resulting particle sizes to be very small.

Figure 2 shows a system in accordance with the present invention. Again, the apparatus is built around a VSI 21, for example a Barmac Duopactor 4800 with suitable modifications. The feed material is supplied to the VSI 21 wet along a supply line 22 via a pump 23. Ground material is fed from the VSI 21 along outlet line 24 to a hydrocyclone classifier 25. Fine particles are passed along outlet 26 for disposal or further processing, while oversized particles and liquid return along feed line 27 into the supply line 22. Valves 28, 28a are provided in the supply line 22, so as to control flows to inlet lines 29,30. Recycled slurry and new material passing along the line 30 enters the rotor feed tube of the VSI 21 in the normal way. Recycled slurry and new material passing along line 29 can also be introduced through the top of the VSI 21 to a cascade device in more than one position, and it thus cascades past the rotor. Adjustment of the valves 28 and 28A allows alteration of the relative rates of flow along the lines 29 and 30.

Figure 4 is a schematic diagram showing a vertical shaft impactor, specifically a specially adapted 4800 Barmac Duopactor (Trade Mark), which may be used in the system in accordance with the invention. The VSI has a first inlet 70 which receives solid feed material together with a controlled amount of liquid which enters via manifold 71; additional liquids are introduced by manifolds 72 which deposit the liquids onto a cascade plate 73. The proportional distribution of these liquids between manifolds 71 and 72 is controlled by valves 74 and 75. The introduced liquids may also carry solid particles which may be additional feed material or the oversize materials as rejected by a classifying device installed within the further processing system.

The valves can be controlled such that, for a given energy input to the rotor of the impactor, desired results are achieved in terms of material throughput and resulting particle size distributions. It is advantageous to return some of the oversized material to the rotor because the added liquid assists in the grinding process. However, energy is saved if most of the oversized material is passed to the cascade inlet and does not enter the rotor. This is because, on average, the "oversized" ground material will have smaller particle sizes than the raw feed material. Greater energy efficiency can be obtained by passing the raw feed material to the rotor, since it is this material which requires more effort to reduce its average particle size.

The solids/liquid mix which enters the first inlet 70 passes through control tube 76 and the rotor feed tube 77 which are connected together by a sleeve 78 and which direct the solids/liquid feed material into the rotor 79. From the rotor 79 the feed mix is flung outwardly into the grinding area 80. The grinding area contains a bed of the solid material which is being ground, but may alternatively be filled with special wear-resistant steel anvils or similar materials.

At the same time, the liquid being fed onto the cascade plate 73 from the manifolds 72 cascades downwards into the flow of material which is being flung outwardly from the rotor 79.

Figure 5 shows an alternative embodiment of the grinding apparatus which may be used in the system shown in Figure 2. Again, the apparatus is in the form of a specially modified VSI based on part of a 4800 Barmac Duopactor.

The VSI has a first inlet 170 to receive solid or semi-solid feed material together with a controlled amount of liquid which enters via manifold 171 and is controlled by valve 174; additional liquids are introduced by a manifold 172 which is controlled by valve 175.

As also shown in Figure 6, which is a partial cross-section through the apparatus shown in Figure 5, the liquid is introduced by a manifold 172 which is in the form of a ring. The inner wall 183 of the manifold 172 is perforated, and the liquid passes through the perforations 184 into an annular inner region 185. Again, the inner wall 186 of the annular region 185 is perforated, and liquid is forced through the perforations 187 into a thin annular region 188 having a small radial dimension, the inner wall 189 of this region being solid. From the thin annular region 188, the liquid, and any entrained solid particles, are able to fall vertically downwards into the grinding region 180. It is advantageous that the material enters the grinding region moving vertically and with no radial velocity, or only a small radial velocity, as this improves the grinding which is achieved. At the same time, material introduced through the first inlet 170 and the tube 177 which passes through the centre of the manifold 172, is being thrown outwardly from the rotor 179. Thus, in the grinding region 180 there are high autogenous attrition forces, which result in highly effective grinding of the material.

In addition there are located in the grinding area special self-adjusting shear plates 182 which enhance the grinding action especially of the larger material particles.

The shear plates take the form of flat plates which are mounted in the grinding region. The plates are pivotally mounted such that, as material exits the rotor, the plates are deflected so that their inner edges act as shearing edges on the material exiting the rotor. These edges are advantageously protected by wear resistant material. In the illustrated embodiment, the shear plates are suspended on bars which are located approximately one third of the way along the plate, such that the plates are easily replaceable. Any desired number of such shear plates can be chosen to be circumferentially spaced around the rotor as required. As an alternative, the shear plates may be replaced by a grinding ring, or breaker ring, in the form of a continuous ring which may be set into the grinding region, either in segments or in one piece, and which has a sharp corrugated surface to improve the initial breakage of large material exiting the rotor.

Further, or as an alternative to the shear plates or grinding ring, the efficiency of the grinding process may be improved by the addition of heavy massing agents, which can assist in the grinding process without themselves being broken down very quickly so that they are rejected by any classifying device which is used and thus can be recirculated around the system. These massing agents are made of a material which is preferably several times as dense as the material being ground, and is preferably highly ductile, so that they have high kinetic energies during the grinding process and hence enhance the reduction of the material to be ground, but are able to withstand the high forces exerted on them for a useful period of time. For example, the massing agents may be steel ball bearings, steel discs or other suitable steel objects. Of course, any material chosen in this way must also be selected so that it does not contaminate the final ground product.

Figure 3 shows an alternative embodiment of the invention, for use in a hybrid process in which the feed material is originally fairly dry, but may for example be oil- or water-based cuttings, which are relatively glutinous. It has surprisingly been found that wet grinding of these cuttings, in a system according to the present invention, has remarkably beneficial effects.

The system includes a VSI 41, to which the feed material is supplied along a controlled conveying device 42. The VSI 41 is preferably as illustrated in Figure 4 or Figures 5 and 6 of the drawings. Ground material leaves the VSI and enters a liquid-filled tank 43 which is designated the coarse slurry tank. Adjacent to this tank 43 is a second tank 44 designated the fine slurry tank. These tanks are connected by an adjustable weir gate 45 and a balancing line including a valve 46. Liquid in these tanks 43 and 44 is introduced from a flow line 47, and the flow is controlled by valves 48, 49 and 50.

Ground material leaves the VSI and enters the coarse slurry tank 43. Some settlement of the material takes place in this tank, and the finer fraction of the slurry passes to tank 44 via the weir gate, the height of which is adjusted to give the required fineness and flow.

The fine slurry is removed from tank 44 by a pump 51 along a flow line 52 to hydrocyclones 56. It will be appreciated that washing screens or other classifying devices may be used. The flow to these classifying devices in the flow line 52 is controlled by a valve 53. There is also a bypass system such that excess fine slurry can be returned to the coarse slurry tank 43 via line 54 and control valve 55, if desired.

The fine fraction of the slurry, having been classified to the desired specific gravity or particle size, is passed to a storage facility by line 57 for further process applications.

The coarse fraction of material leaving the classifying device 56 passes to a catchment hopper 58 where it can be flushed by liquid from line 47 and then passed to line 59 where by means of pump 60 it is returned to the inlet side of pump 61.

Pump 61 is mounted adjacent to the coarse slurry tank 43 and takes coarse slurry from the tank 43 plus classifier oversize from the line 59 and passes this material to the VSI 41 along flow line 62.

Flow line 62 introduces the coarse slurry to the VSI 41 in two positions along flow line 63 and 64. The flow of slurry to these two lines is controlled by valves 65 and 66. To maximise the efficiency of the grinding process, it is preferable if the majority of the slurry is supplied to the cascade input of the VSI 41 along flow line 63, while raw feed material is supplied to the VSI with only sufficient liquid to prevent the build up of material in the feed hopper. This is because the returned material contained in the slurry will, on average, have smaller particle sizes than the raw feed material, and hence greater efficiency can be achieved by preferentially using the input energy, which is supplied by means of the rotor of the VSI, in the grinding of the raw feed material.

Thus, it is possible both to introduce coarse slurry along with the primary feed material but also to arrange to pass coarse slurry to the cascade device as previously discussed. In this manner it has been found that grinding of mineral material can be accomplished in a liquid environment where densities, particle distributions or chemical characteristics can be influenced and controlled.

Claims

1. A grinding system including a vertical shaft impactor grinding apparatus, the grinding apparatus comprising:

a feed hopper (70,170) defining a first inlet for feed material;

a rotor (79,179); and

an outlet;

the rotor being mounted such that it can rotate in the apparatus; and

the feed hopper being connected to a feed tube (78,177) which directs all of the inlet feed material from the first inlet to the rotor such that it is flung outwardly by the rotor into a grinding region (80,180), and the system further including:

a classifier (25), for separating oversized ground material from material removed from the grinding apparatus;

a first supply line (24), suitable for transporting ground material within a liquid from the outlet to the classifier; and

a second supply line (27,22), suitable for returning separated oversized ground material within a liquid from the classifier to the grinding apparatus.

2. Apparatus as claimed in claim 1, wherein the vertical shaft impactor has a first inlet (70,170), through which feed material is supplied to the rotor, and a second cascade inlet (72,172), wherein a first fraction of the oversized ground material may be returned to the impactor via the first inlet and a second fraction of the oversized ground material may be returned to the impactor via the cascade inlet such that it can cascade past the rotor.

3. Apparatus as claimed in claim 2, wherein a control device such as a valve (28,65) is provided in the second supply line allowing the relative volumes of the first and second fractions to be varied.

4. Apparatus as claimed in claim 2, wherein the second inlet comprises a plurality of pipes for directing inlet feed material on to a cascade plate (73) located above the rotor such that said material cascades into the grinding region.

5. Apparatus as claimed in claim 2, wherein the second inlet comprises a first region (185), located around and above said rotor, and a second region (188) in communication with the first region such that inlet feed material passes from the first region into the second region and then falls down in to the grinding region.

6. Apparatus as claimed in any preceding claim, wherein the ground material is passed to a liquid-containing tank (43), the tank being provided with means for separating the ground material into a coarse fraction with relatively large particle sizes, and a fine fraction with relatively small particle sizes, the coarse fraction being returned to the input of the apparatus and the fine fraction being passed to a classifying device (56) to separate the fine fraction into a first fraction containing particles of desired sizes, and a second fraction containing oversized particles which are returned to the input of the apparatus.

7. Apparatus as claimed in claim 6, wherein the liquid-containing tank (43) is provided with an adjustable weir device (45), such that the fine fraction of the ground material is passed to a second tank (46), the second tank being provided with a pump (51) to supply material to the classifying device (56).

FIG. 1

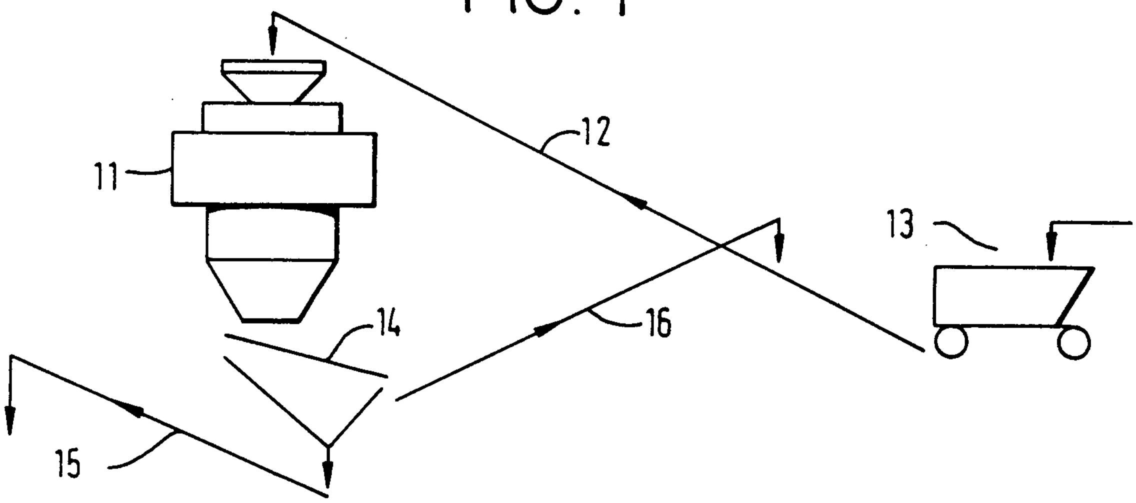

FIG. 2

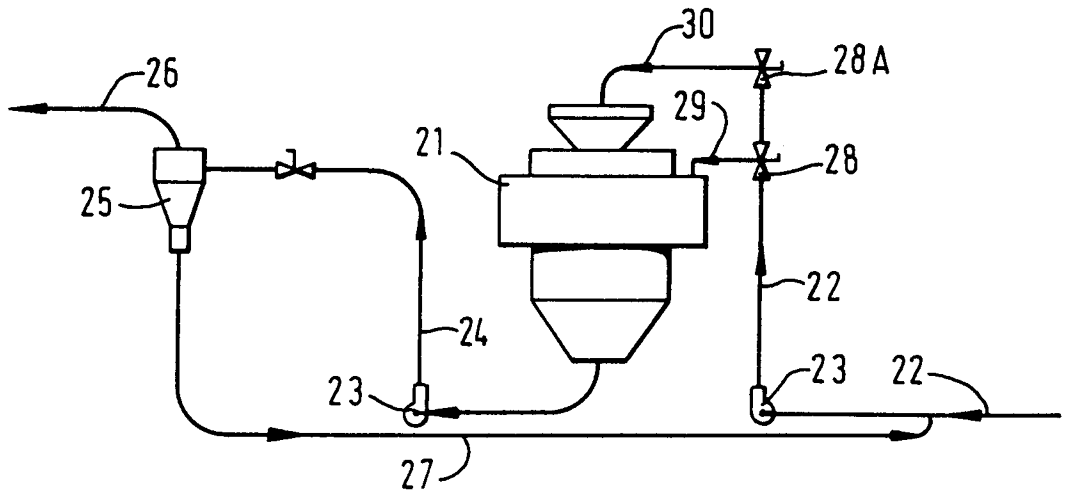

FIG. 3

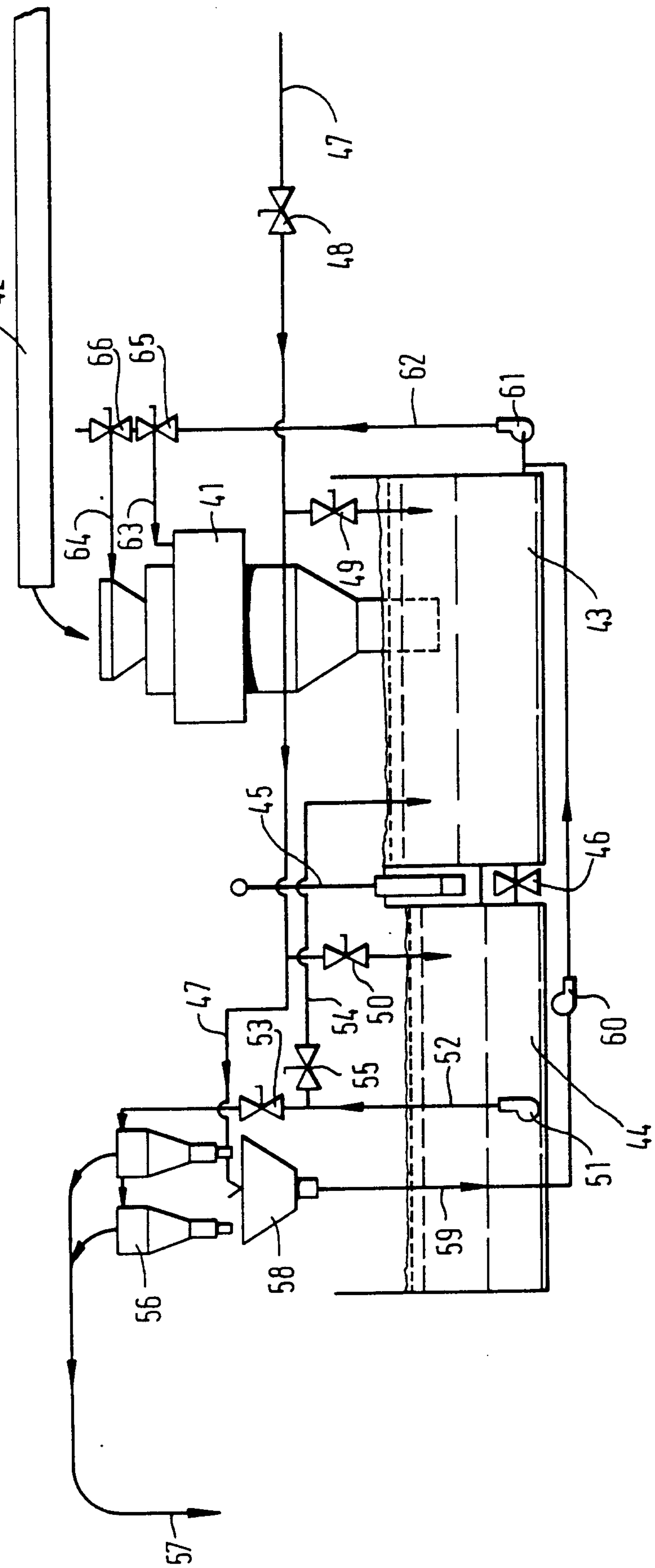
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FIG. 4

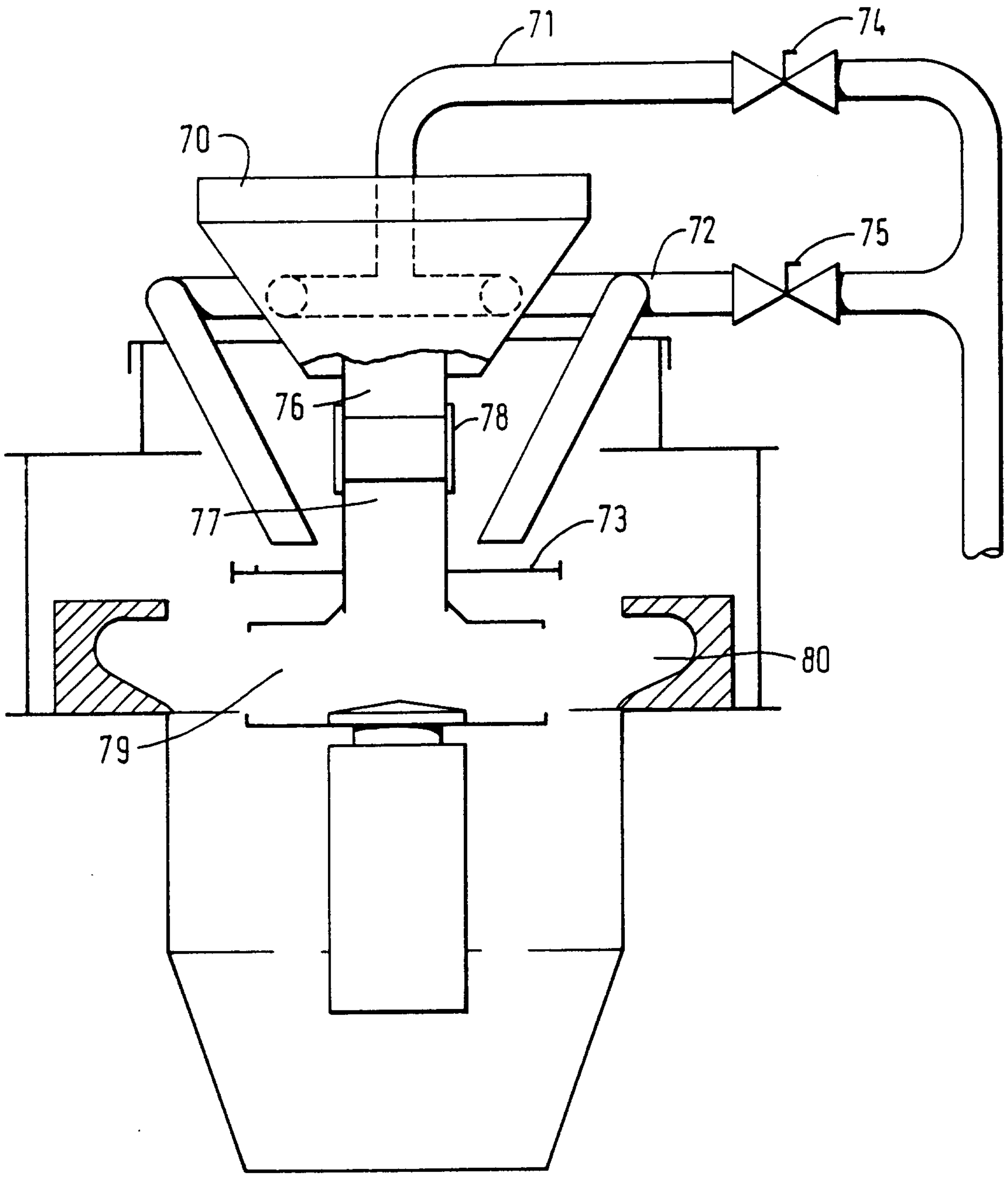

FIG.5

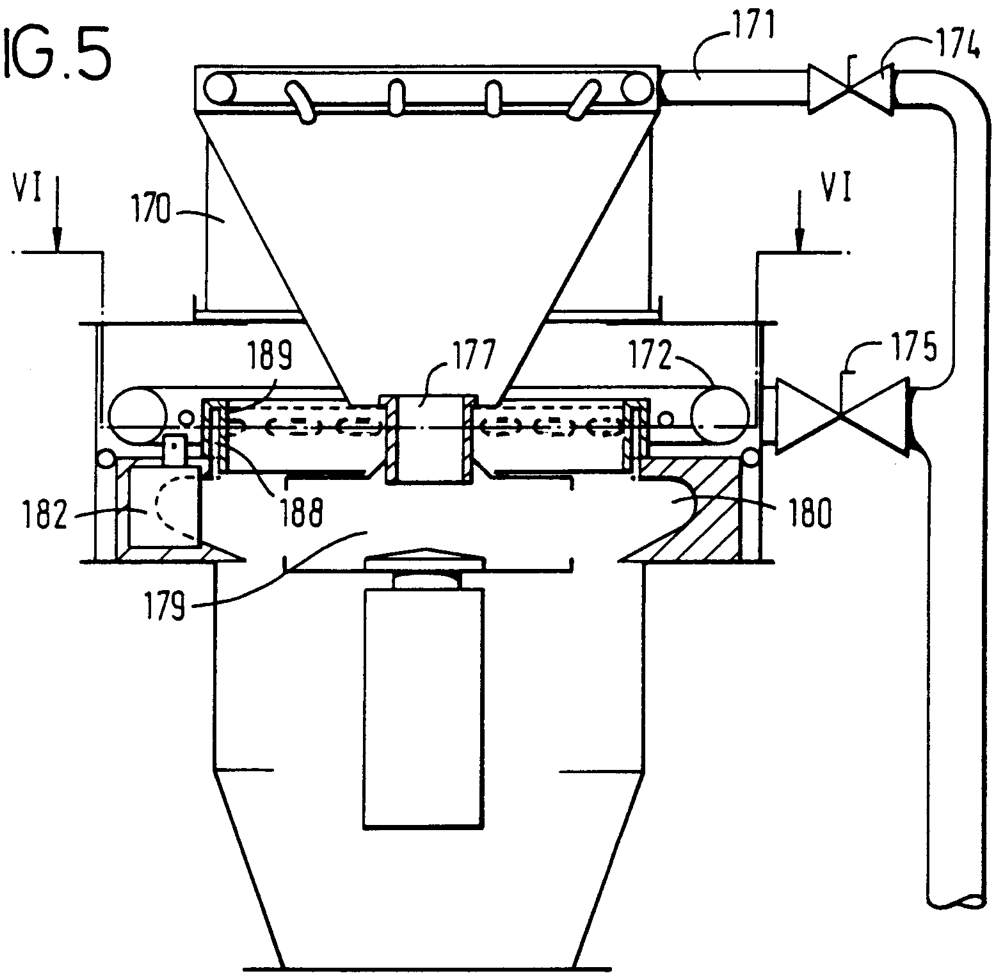
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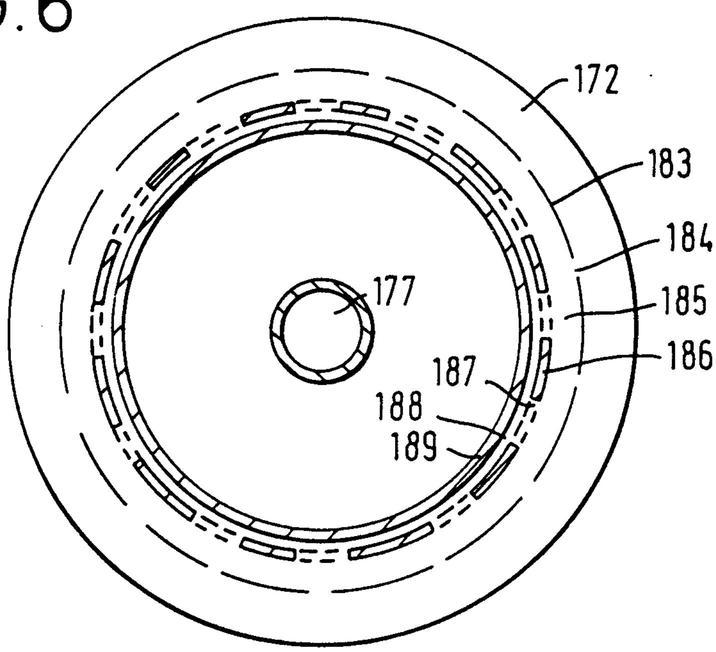
FIG.6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EUROPEAN SEARCH REPORT

Application Number
EP 95 10 6823

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.5)
A	US-A-4 641 787 (C.C. PETERSEN) * column 3, line 61 - column 6, line 10 * ---	1,2	B02C19/00
A	GB-A-1 268 242 (J. RUZICKA) * page 5, line 23 - page 6, line 51 * ---	1	
A	GB-A-2 120 112 (UNITED STATES GYPSUM CO.) * the whole document * -----	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.5)

B02C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 June 1995	Verdonck, J

CATEGORY OF CITED DOCUMENTS

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