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(54) **Multiple stage comminution device.**

(57) A material handling device intended for providing finely comminuted material or which may be used as a mass transfer device or as a chemical reactor involving providing comminuted material to provide freshly exposed reactive surfaces comprises a housing (10) having a central chamber divided into a plurality of stages defined by rotary support means (18). The housing has a central axis (16) and a plurality of rotating masses (42, 44, 46) are provided, each such rotating mass being mounted on a flexible axle (36, 38, 40), said axles being parallel to the axis of said chamber. Means are provided to cause rotation of said support means (18) about the axis (16) of said chamber whereby the outer surface of said masses contacts the inner surface (14) of said chamber to cause crushing forces to handle material passing through the apparatus, the crushing forces being a combination of centrifugal and gyroscopic forces.

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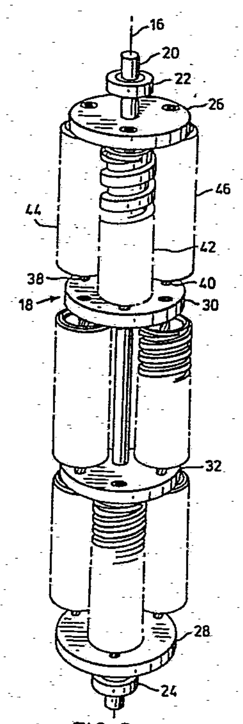

FIG. 2

Title: Multiple Stage Comminution Device

This invention relates to multi-stage apparatus for processing materials. Specifically, it relates to apparatus which may be used for comminuting particulate material, or which may be used for mixing materials or for other operations as will be described.

Numerous devices exist for obtaining very fine material by comminution. These devices are generally complex and expensive, and the degree of fineness to which they comminute material is usually limited.

A device has been developed which provides a substantial improvement over previously known devices. This device is described in Canadian Patent No. 974,956 issued September 23, 1975. An improvement of the device has been described and claimed in co-pending Canadian Application No. 235,623 filed September 17, 1975. In co-pending Canadian Application No. 235,623 a mass is rotated in a chamber, the mass being mounted on a flexible axle, for example, a wire rope.

The device disclosed in co-pending Canadian Application No. 235,623 is a single stage device comprising one or more rotating masses. In many cases it is required that the material to be handled in the apparatus should be given a longer residence time. Residence time in grinders of the type referred to in the previous patents is important as the size reduction during the grinding or mixing process is directly dependent upon the residence time. Thus, where a substantial reduction in particle size is required it is often necessary to recycle material. In other cases where very fine grinding is required it may be necessary to ensure that the residence time is relatively long. Such devices in addition to providing pure mechanical grinding are particularly useful in various mass transfer operations and chemical reactions. The grinding devices may be used in such operations as leaching or extraction into a liquid. Such mass transfer processes require appropriate residence times to obtain the desired result. With a single stage device such residence time can only be controlled by recycling the material.

As stated in co-pending Canadian application No.235,623 the residence time within the apparatus and the degree of size reduction in a pass through the apparatus is dependent in large measure upon the configuration of the masses. Where the mass is provided with relatively large helical extending grooves the size reduction will be substantially smaller than the case of a helical mass having relatively small grooves. In addition, the transport rate through the apparatus will also be influenced in part by the number and pitch of the helical grooves.

According to this invention there is provided a multi-stage unit, each such stage comprising a plurality of grinding masses mounted on flexible axles. The configuration of the masses in each of the stages may be chosen to give the desired result in terms of size reduction of particles and residence time all as may be required for the particular process involved.

According to this invention a material processing apparatus comprises a plurality of masses having an outer surface and a central longitudinal axis wherein all the axes of the masses are parallel. The masses are contained within a housing which has a longitudinal axis and an internal chamber having an interior surface. The longitudinal axis of the housing is parallel to the axes of the masses. Rotary support means are included within the housing for providing rotation about the axis of said housing and for rotatably supporting the masses on flexible axles for rotation about their individual axes. The flexible axles are positioned such that the outer surface of each of the masses contacts the inner surface of the chamber of the housing as the rotary support means rotate about the axis of the housing. The rotary support means comprise a plurality of longitudinally spaced apart support plates which support plates divide the chamber of the housing into a plurality of stages. Each of at least two of the stages comprises at least two of the masses. Mounting of the masses on the flexible axles provides a combination of centrifugal and gyroscopic forces to act on and crush particles or otherwise process material located between the rotating masses and the chamber wall.

Devices according to the invention may be used either to provide finely comminuted material or for mixing or homogenizing liquids, mixing solid particles, mixing particles with liquids, or they may be used as mass transfer devices and as chemical reactors, comminuting material to provide freshly exposed reactive surfaces which may react with other materials present.

Further features of the invention will appear from the following description of a preferred embodiment of the invention, taken with the accompanying drawings, in which:

Figure 1 is a cross-section through one of the stages of an embodiment of the invention;

Figure 2 illustrates the rotating means contained within the housing illustrated in Figure 1;

Figure 3 is a cross-section illustrating means for mounting one of the masses illustrated in Figures 1 and 2;

Figure 4 illustrates the flexible axle and its fittings illustrated in Figure 3;

Figure 5 illustrates the arrangement of attachment of flexible axles to one of the rotating support plates illustrated in Figure 2;

Figure 6 illustrates an alternate embodiment of the invention in vertical section;

Figure 7 illustrates a further embodiment of a rotary support plate having means to assist material movement through the apparatus, and

Figure 8 is similar to Figure 2 and illustrates another embodiment of the rotating means.

Reference is first made to Figures 1 and 2. The apparatus indicated generally as 10 comprises a housing 12 having an inner surface 14. The housing is an elongated tubular housing having a central axis 16 and is arranged of convenient length to incorporate the number of stages desired.

The rotating mechanism contained within the housing is shown in Figure 2. The rotating means indicated generally at

18 comprises a central shaft 20 extending the full length of the housing. Shaft 20 is concentric with the central axis 16 of the housing. The shaft 20 is located within the housing by means of upper and lower bearings 22 and 24 respectively. Affixed to the central shaft 20 are a plurality of support plates. In the embodiment illustrated there are four support plates comprising upper support plate 26, lower support plate 28 and central support plates 30 and 32. The support plates affixed to the shaft 20 divide the chamber contained within housing 12 into a series of individual grinding compartments or stages. As the support plates have a diameter less than the internal diameter of the housing 12 the compartments are connected in series by the annular gap between the support plates and the inner surface 14 of the housing 12. This gap is shown as 34 in Figure 1. The width of this gap may be varied as required by the particular process to be carried out in the apparatus as will be more fully explained hereinafter.

With reference to Figure 2 it may be seen that extending between upper support plate 26 and central support plate 30 are three flexible axles 36, 38 and 40. Mounted on each of the flexible axles is a rotating mass 42, 44 and 46 respectively. As will be apparent from Figure 1 it may be appreciated that the flexible axles are mounted in the support plates such that with the diameter of the mass chosen the outer surface of each of the masses contact the inner surface 14 of the housing 12 when the apparatus is at rest. Each mass is mounted on the flexible axle for rotation of the mass about the flexible axle. Accordingly, as the entire rotating means rotates about axle 20 each individual mass will rotate about its flexible axle as the surface of the masses contact the inner surface of the housing 12.

Figure 3 illustrates the means of mounting the masses on the flexible axles and the mounting of the flexible axles in the support plates. Figure 3 illustrates by way of example rotating mass 42 mounted on flexible axle 36. Flexible axle 36 which is illustrated in greater detail in Figure 4 comprises two swaged fittings on either end. Swaged fitting 48 is swaged to the wire rope 50 and comprises a groove 52 for retention of a snap ring 54. Swaged fitting 56 is attached to wire rope 50 at the other end of the rope and comprises an external thread 58 adapted to receive nut 60. The flexible axle 36 also comprises a central fitting 62 swaged to the central portion of the rope for mounting of bearings upon which the mass may be mounted.

The assembly of the flexible axle is illustrated in section in Figure 3. It will be observed that the flexible axle extends between upper support plate 26 and central support plate 30. In order to assemble the mass 42 to the flexible axle two bearings 64 and 66 are first mounted on the swaged central fitting 62. The mass 42 is then axially moved along the wire rope until it is centrally located over the bearings. Collar 68 is then inserted from the top. Collar 68 bears against bearing 64 and is retained in place by a snap ring 70. The collar 68 comprises a dust seal 72 intended to prevent dust and other like products from affecting either of the bearings 64 and 66.

A similar collar 74 bears against bearing 66 and is retained by snap ring 76 retained in a groove in the interior surface of the mass 42. Collar 74 also comprises a dust seal 78 to isolate the bearings from the grinding products.

Once the mass 42 has been assembled to the flexible axle 36, then the axle is assembled first to support plate 26. Support plate 26 includes a hole to snugly receive swaged fitting 48. Swaged fitting 48 projects through the hole in support plate 26 such that the retaining ring 54 may be then placed in groove 52 to affix the fitting 48 to plate 26. The flexible axle 36 is then long enough to ensure that fitting 56 will project through a similar hole in central support plate 30. The two holes in support plates 26 and 30 are so arranged that when the flexible axle has been firmly affixed to the plates the mass 42 will be mounted having its longitudinal axis parallel to shaft 20. Fitting 56 projects through support plate 30 to expose a portion of thread 58. Nut 60 may then be threaded on to fitting 56 to as to securely locate the flexible axle and its rotating mass 42.

Mounted in the manner suggested hereinbefore it will be appreciated that mass 42 is adapted to rotate about its flexible axle 36. The flexible axle permits the mass to move radially outwardly as the shaft 20 rotates thereby ensuring that the outer surface of mass 20 remains in contact with the inner surface 14 of the chamber 12. However, when a particle to be crushed moves between one end of the mass 42 and the surface 14, this tends to cause the mass 42 to tilt. The tilting of the rapidly rotating mass about its own axis creates a gyroscopic restoring force causing an additional crushing force to be exerted on the particle. The axial length of the mass 42 is a matter of choice. However, it should be observed that if the mass is made unduly long then tilting of the mass may cause an extensive loss of contact area between the mass and the inner surface of the chamber. Accordingly, where the tilting masses are used much more efficient grinding is possible where there is a plurality of stages of grinding as compared to using a single mass having a length equivalent to the several stages.

Although it may be possible to use a single rotating mass in each stage it is preferable to use at least two rotating masses in each stage in order to have a balanced device. It is considered that in most applications it will be preferable to use three or more rotating masses at each stage. If three rotating masses are used then the masses should be arranged in a balanced configuration as shown in Figure 1. As shown in Figure 1 the three masses will be distributed about the support plate such as to present 120° of arc between attachment points. Upper and lower support plates 26 and 28 thus will be provided with three holes for location of three flexible axles. Central support plates 30 and 32 can advantageously be fitted with six support holes arranged at 60° intervals around the arc of the support plate.

Figure 5 illustrates central support plate 30. It will be observed that flexible axles 36, 38 and 40 are arranged around the arc at 120° intervals. Flexible axles 80 and 82 of the central stage are attached to central support plate 30 midway in between the attachment points for the flexible axles for the upper stage. The third flexible axle for the central stage would be located in Figure 5 behind the central shaft 20. Using this system of attachment a single central plate may be used to locate the flexible axles immediately above and immediately below the central plate.

When the grinding apparatus is orientated in the vertical position as shown in the figures it is intended that material would be fed by gravity or pressure to the upper stage and allowed to pass through the various stages of the apparatus. There are a number of factors which influence material movement through the apparatus. These are gravity, screw conveying capacity, random bouncing and air or liquid stream pressure. The effect of gravity will be obvious. The screw conveying effect will depend on the form of the surface of the mass. It is suggested that the most convenient form of mass is a mass having a helical groove on the outer surface of the mass. The configuration of the groove, the pitch of the groove and the number of starts to the helix will all determine the screw conveying capacity of the mass. Random bouncing is the term used to take account of the effect that as material is fed into the apparatus it may move in any direction resulting from contact with any of the grinding surfaces or indeed other material within the grinder. The fourth factor is the air or liquid stream. This may arise when the apparatus is used with a forced pressure feed such as might be the case when handling slurries or like fluids. If the fluid is pumped into the apparatus under pressure then the rate of travel through the apparatus will of course be dependent upon the inlet pressure.

Figure 2 illustrates an embodiment of the invention wherein the configuration of the masses is particularly useful in the grinding of coal or other like coarse materials which are relatively easy to feed initially. With such materials it is suggested that the masses in the stages may be arranged with appropriate combination of groove size, pitch and number of starts to the helix to achieve the desired grinding in each stage. As illustrated in Figure 2 the first or upper stage comprises three masses each having an outer surface comprising a helical groove. The groove is a single start helix and is relatively wide with relatively large pitch. In this stage it might be expected that lumps of coal having a mean diameter as large as 1 to 2" might result in an output from this stage of lumps having a mean diameter of approximately 1/8". In the second stage the masses also have an outer surface comprising a helical groove. However, in this stage the helix which again has a single start would comprise a finer groove, narrower, measured parallel to the axis of the mass (approximately 1/2 the groove width of the first stage). In addition the pitch of the helix is less (approximately 1/2 that of the first stage). This stage would reduce the 1/8" diameter material to a relatively fine powder. The third stage also comprises three masses. These masses have a helical extending groove on the surface of each of the masses. In this stage, however, a multiple start helix preferably three start, is suggested with a pitch approximately 3/4 of that in the first stage. A more fine groove size (approximately 1/4) is used for the helix. This stage would then be expected to give a very fine product.

A further embodiment is illustrated in Figure 8. This embodiment is essentially similar to that shown in Figure 2 except that the device has been designed for handling materials which are generally more difficult to feed initially. Each of the three stages comprises three masses and all of the masses have helical extending grooves. With product which is initially difficult to feed it is suggested that the device should be designed such that the masses in the initial stages have increased transport capabilities over the masses of the subsequent stages. In this embodiment, the masses of the first stages comprise a triple start helical extending groove of relatively large pitch. The masses of the second stage comprise a double start helical groove of relatively less pitch than that in the first stage. The masses of the third stage comprise a single start helical groove having the smallest pitch, perhaps as small as 1/3 of the pitch in the first stage.

By varying the transport capabilities of the helixes in the manner discussed above, appropriate residence time in each stage can be achieved. If particularly increased residence time is necessary it is even possible to arrange the helical groove so as to counteract the effect of gravity.

When the apparatus is being used as a reactor or a mass transfer device then the question of residence time becomes all important. The residence time may be controlled in each stage by means of the configuration of the helix used in the stage. The net flow through the device must however, be constant as each stage feeds serially to the next stage. If the apparatus is being used to provide a slurry mixing and grinding operation the mill can be run full of slurry. Good grinding will result even though the mill is full. Alternatively, the mill can be run in what is referred to as a low hold-up condition. When run in the so-called low hold-up condition centrifugal force keeps the slurry distributed about the outside of the central chamber of the housing and good grinding is achieved with relatively low power use. As long as the slurry remains essentially on the outside of the chamber then there is no power loss due to stirring of the slurry in the internal or central portions. This also gives an essentially plug flow with more uniform size reduction along the longitudinal axis of the apparatus.

When considering residence time the question of flow between stages may become critical. Annular gap 34 illustrated in Figure 1 between the central support plate and the surface of the housing 12 will affect the rate of flow. If relatively large diameter rotating masses are used, then the flexible axles will be located radially inwardly toward the central shaft 20. This will allow for a relatively large annular gap. In certain instances it may be desirable to provide additional room for flow of material between stages. This may be accomplished by ensuring that the support plates occupy no more area than is necessary. One means to achieve this would be to provide each of the plates with a star-shaped configuration rather than a disc configuration. With this type of configuration each of the support plates would be comprised of a star-shaped plate having the appropriate number of arms as are required to support the appropriate number of rotating masses. Also, in order to limit the possibility of a particle falling completely through a stage it is suggested that the rotating masses of adjacent stages should be off-set as explained above. In the apparatus illustrated three masses are used in each stage and the masses are off-set with respect to adjacent stages by approximately 60°.

In certain instances such as when grinding slurries it may be desirable to retard the effects of gravity and in such instances additional structure may be included to reduce the size of the annular gap. Such a device is illustrated in Figure 6. In this figure the housing 12 comprises an annular ring 90 projecting inwardly into the chamber adjacent one of the central supporting plates. Particularly when the apparatus is being used with a slurry in the low hold-up condition as referred to above, the ring will act as a partial dam and slow down the passage of the material through the apparatus.

In other cases particularly as when grinding to particularly fine powders it may be necessary to attach additional apparatus to the central support plates to promote passage of the powder from one stage to the next. Various means may be used to do this such as by incorporating small vanes, fingers or auger-like blading around the edge of the support plate. This is shown in Figure 7. By way of example a finger 92 is illustrated. The number and configuration of such fingers can be chosen for the particular operation. In order to maintain a balanced rotating mass the fingers can best be arranged in balanced relationship.

Depending upon the nature of the material to be fed to the apparatus a relatively large opening may be required at either the top or the bottom or both. In cases where it is desired to run the apparatus in the low hold-up condition it would be desirable to have a relatively large open area at the bottom in order to take full advantage of the gravity effect of material conveyance. In such a case the housing may be entirely open at the bottom and it would be considered desirable to drive the central shaft from a motor located above the apparatus. In other cases where it is desirable to maintain a long residence time in the apparatus such as when the apparatus is used as a chemical reactor, then the bottom may be closed with a suitably small outlet provided and a relatively large inlet. In this case the central shaft 20 may be driven from a single motor located toward the bottom end of the shaft. By using the apparatus as illustrated in these drawings, a single motor source may be used and the number of seals required may be minimized as compared with using a plurality of single stage devices. Use of one single large motor necessitating only one set of controls should result in lower capital cost as opposed to three independent stages.

Throughout this description and in the drawings reference has been made to a device comprising three masses in each stage. The number of masses in each stage, however, can be changed without departing from the scope of this invention. Where a particularly large diameter housing is used then it may be desirable to increase the number of masses in each stage. With very large housing it may be that as many as 6 or 8 or even more masses may be used in each stage. In the preferred embodiment illustrated herein each of the stages has comprised three masses. However, in varying instances and depending upon the product to be processed in the device it may be that a varying number of masses may be used in each stage. The number of masses per stage may be varied either up or down from the embodiment specifically illustrated herein. It should also be realized that the number of stages used may also be increased.

CLAIMS:

1. Material processing apparatus comprising a housing including a processing chamber, a plurality of masses rotatable in said chamber, and drive means to rotate a rotary support means supporting each of said masses for free rotation about its own axis, characterised in that the axes of rotation of said plurality of masses are parallel to a central longitudinal axis of the chamber, and that the rotary support means includes a plurality of longitudinally spaced apart support plates dividing the chamber into a plurality of stages arranged in series, each stage comprising at least one mass which rotates so that it is normally in contact with an inner surface of the chamber, said rotary support means further comprising a plurality of flexible axles, each rotatably supporting one of said masses and extending between two of said support plates along the axis of said mass; said flexible axle thereby supporting said mass to enable radial movement of said mass and to enable tilting of said mass about its axis, so that under rotation imparted by

said drive means to said rotary support means, said mass will be impelled under centrifugal force generally radially outwardly of said rotary support means and will be pressed into contact with said inner surface of said chamber and will roll therearound, and so that said mass may tilt in the presence of a particle located between said outer surface of said mass and said inner surface of said chamber, thereby applying a crushing force constituted by both centrifugal and gyroscopic forces against said particle.

2. The device of claim 1 in which each of said masses rotates about the flexible axle on which it is supported.

3. The device of claim 2 wherein said flexible axle comprises wire rope.

4. The device of claim 3 wherein the masses of one stage are circumferentially offset from the masses of the next adjacent stage.

5. The device of claim 2 wherein the masses of one stage are circumferentially offset from the masses of the next adjacent stage.

6. The device of claim 4 wherein at least one of said support plates which is located between stages comprises means to support ends of said wire ropes of each stage bounded by said plate.

7. The device of claim 5 wherein at least one of said support plates which is located between stages comprises means to support ends of said flexible axles of each stage bounded by said plate.

8. The device of claim 2 wherein at least one of said support plates has the configuration of a disc and material processed in said device passes through the annular gap defined by the periphery of said plate and said inner surface.

9. The device of claim 2, claim 6 or claim 7 wherein at least one of said plates comprises a plurality of radially extending arms and flexible axles supported by said plate are fixed to said arms.

10. The device of claim 8 wherein said plate comprises means to assist transport of said material through said gap.

11. The device of claim 8 wherein said housing further comprises means extending radially inwardly of said inner surface located adjacent said plate to retard passage of material being processed through said gap.

12. The device of claim 3 comprising at least three stages wherein the masses of each stage have an outer surface having the configuration of a helix.

13. The device of claim 12 wherein the transport capability of the helixes of the masses in the first stage is greater than the transport capability of the helixes in the second stage.

14. The device of claim 12 wherein the transport capability of the helixes of the masses in the first stage is less than the transport capability of the helixes in the second stage.

15. The device of claim 12 wherein, the masses of the first stage comprise a single start helical groove of a relatively large pitch;

-the masses of the second stage comprise a single start helical groove which is narrower than the groove in said first stage said groove having a pitch less than that in said first stage;

-the masses of the third stage comprise a three start helical groove which is narrower than the groove in said second stage, said groove having a pitch less than that in said first stage.

16. A device of claim 13, wherein;

-the masses of the first stage comprise a triple start helical groove of relatively large pitch;

-the masses of the second stage comprise a double start helical groove which is of less pitch than in said first stage; and

-the masses of the third stage comprise a single start helical groove which is of less pitch than in said second stage.

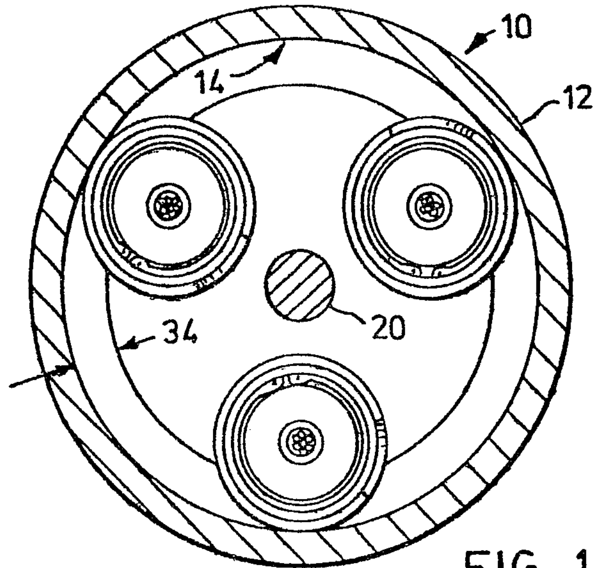

FIG. 1

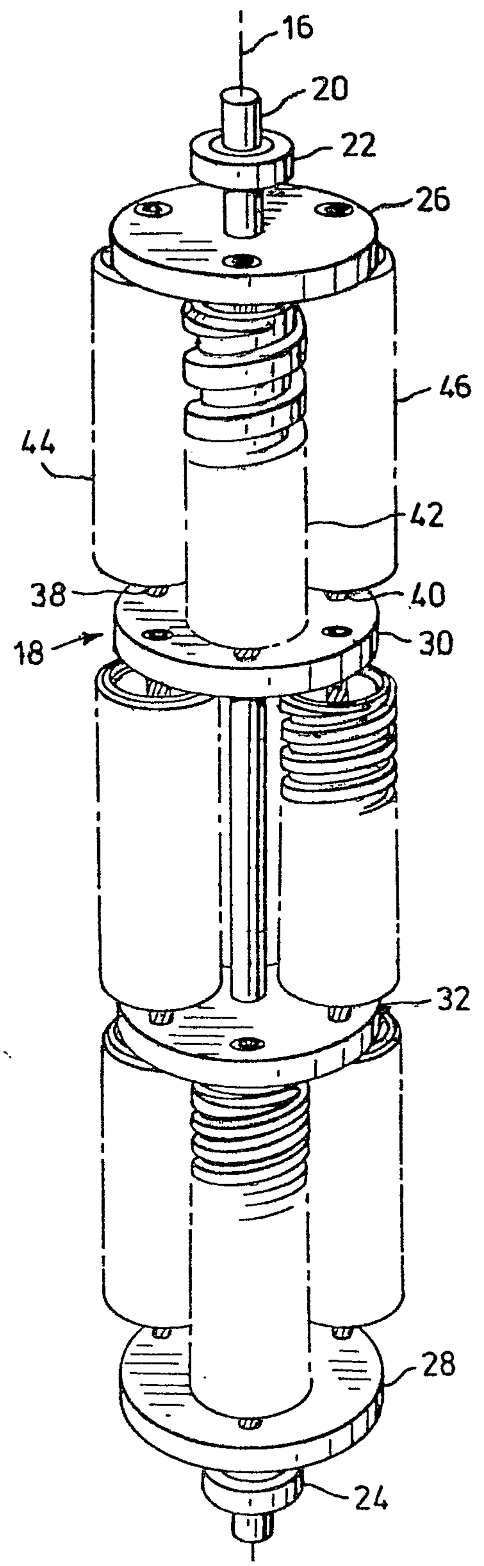

FIG. 2

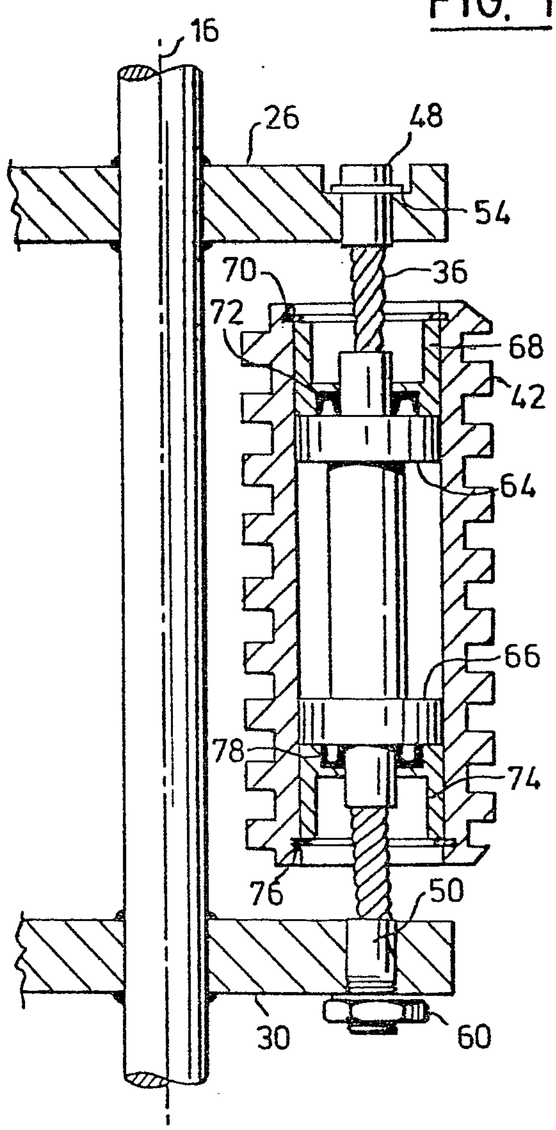

FIG. 3

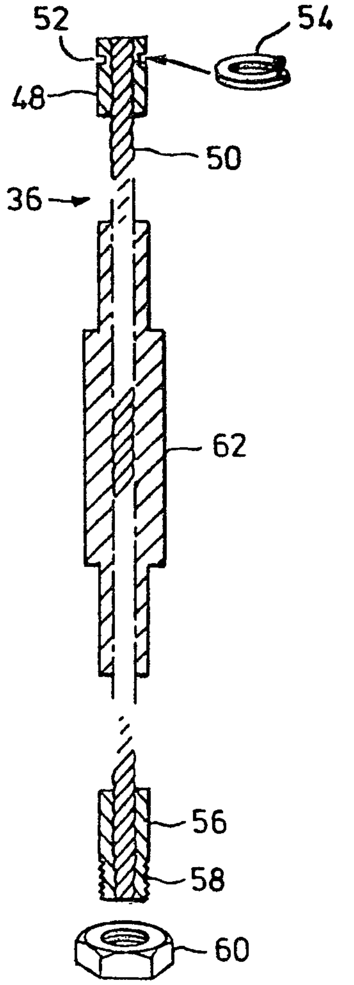

FIG. 4

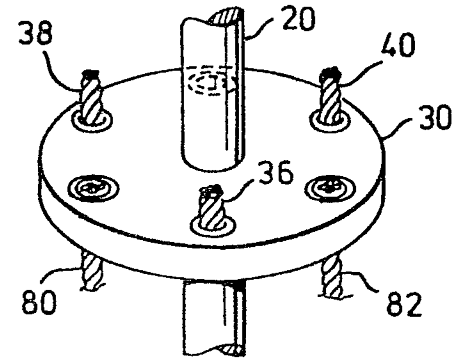

FIG. 5

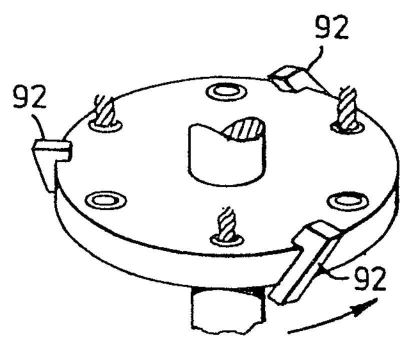

FIG. 7

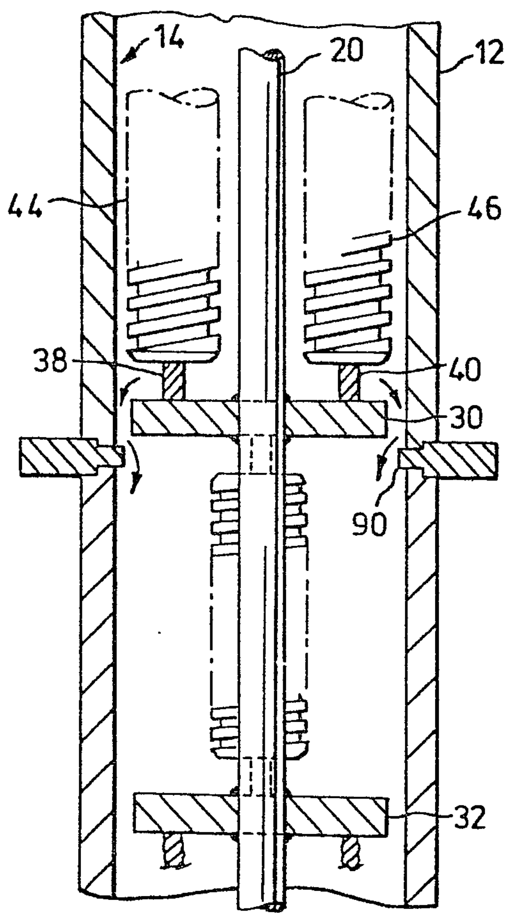

FIG. 6

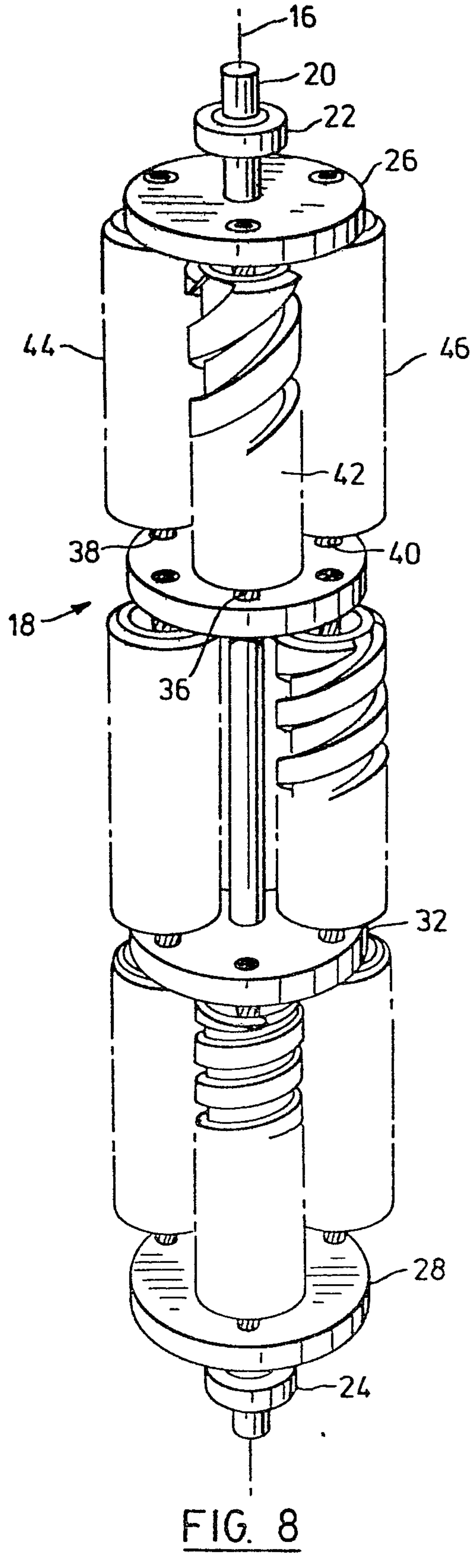

FIG. 8

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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 80 30 4215

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
	GB - A - 1 324 158 (CARLE & MONTANARI) * Page 1, lines 72-92; page 2, lines 1-21 * --	1
	DE - C - 77 732 (WEGENER) * Page 2, left-hand column, lines 51-59; page 2, and page 3 claim 1 * & GB - A - 9739 AD 1894 --	1
	GB - A - 311 329 (GERNELLE-DANLOY) * Page 3, lines 1-27 * --	1,12
	US - A - 3 764 079 (CONSOLI) * Column 3, lines 17-21; column 4, lines 1-12 * --	1,12
D	GB - A - 1 522 813 (GENERAL COMMINUTION) * Page 4, lines 122-130; page 5, lines 1-26 and 43-45, 56-59 * ----	1,2,3, 12

CLASSIFICATION OF THE APPLICATION (Int. Cl.3)

B 02 C 15/08

TECHNICAL FIELDS SEARCHED (Int. Cl.3)

B 02 C

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	27-02-1981	VERDONCK