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(54) Improved vertical microsphere mill, particularly for dispersing pigments in a fluid medium.

(57) A vertical microsphere mill for dispersing a pigment in a fluid medium, wherein a rotor (31) provided with impellers (41) with different diameter and thickness interspaced by shaped spacers (42) also with different diameter and thickness, is inserted in a truncated-cone chamber (12) defined in a casing (2) wherein there is contained a grinding means, for example microspheres or sand, and wherein said chamber is continuously fed with a mixture of pigment and of fluid medium.

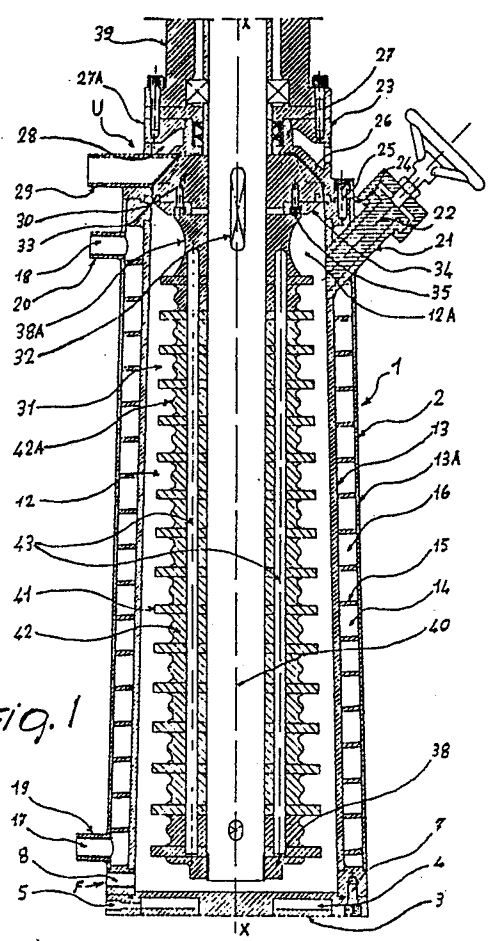

Fig. 1

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IMPROVED VERTICAL MICROSPHERE MILL, PARTICULARLY FOR DISPERSING PIGMENTS IN A FLUID MEDIUM

The present invention relates to vertical microsphere mills of the type comprising a grinding chamber and a rotor rotatably mounted in said chamber to disperse a pigment in a fluid medium, by means of a grinding means, for example microspheres, contained in said chamber.

In the chemical industry, and specifically in the paint industry, the need arises to disperse a pigment or several pigments simultaneously in a fluid medium constituted by resins and solvents, causing the disgregation and the breakup of agglomerations of said pigment into elementary particles thereof and causing the fluid medium to coat every single particle, fully wetting its outer surface.

To meet this need, so-called sand or microsphere mills of the type specified above are known and widely used, wherein the desired dispersion is achieved by imparting to the mixture (pigment + fluid medium) speed gradients so as to subject it to the action of shearing forces. The grinding means, sand, microspheres and the like, contained in the mill, accelerates the dispersion favouring the disgregation and the breakup of the agglomerates of pigment.

This is essentially due to the coexistence of two phenomena during the operation of the machine:

1) the collisions which are generated between the individual particles in motion,

2) the presence of the grinding means (microspheres or sand) which causes an increase in the viscosity of the system (mixture + grinding means) although this is a heterogeneous system.

The increase in viscosity generates, for equal speed gradients dv/dx, greater shearing forces

$$\tau = \eta \frac{dv}{dx}$$

An example of known mill of the specified type is the one commercially known as "Chicago Boiler". Said mill is constituted by a cylindrical chamber containing a plurality of rings with equal diameter and thickness arranged at equal distance, supported by the rotor by means of spokes which cause the desired dispersion of the pigment in the fluid medium.

These mills, being of the "open" type, favour, during operation, the emission into the atmosphere of solvent vapours; the phenomenon is enhanced as an effect of the temperatures of the product in output (60-70°C) and therefore such mills require auxiliary devices such as aspirators or dampers. Furthermore, mills of this type, though substantially compliant with the purpose, require high power for the actuation of the rotor, due to the large amounts of grinding means used. They are normally equipped with an electric motor or approximately 30-KW. A prolonged permanence of the pigment-fluid medium mixture within the mill is furthermore necessary, and accordingly in said known mills the flow rates must be limited to achieve the desired degree of dispersion of the former in the latter.

The machines at issue are furthermore configured so that the cleaning operations for changing the colour (washing with solvent) are particularly complicated, expensive and harmful; the causes of this disadvantage being mainly two:

1) the formation, during operation, of dead zones between rings where the medium + pigment mixture is scarcely moved. The scarce movement, added to a deficient cooling system (for these machines, internal operating temperatures are in the range of 70-80°C), facilitates the formatiön of scale having high thickness (23 cm), constituted by partially polymerized resin and grinding means, on the innermost walls of the rings and on the rotating shaft. The removal of such scale is possible only with a mechanical action or with combustion and in both cases the stop and the disassembly of the machine are necessary.

2) The large dimensions of the machine itself.

All this, besides causing a reduction of the efficiency of the mill in terms of dispersion, generates local overheatings, due to an irregular distribution of the grinding means.

Mills of the closed type are also known, commercially known under the name "Vollrath", wherein the grinding chamber has a constant square, rather than circular, cross section. This has allowed to achieve, for an equal rotor speed, an improvement of the shearing effect, however it increases the amount of mixture contained in the mill, a part whereof remains in substantially dead zones at the corners of the grinding chamber, and the amount of grinding means which must be available in the grinding chamber increases accordingly.

Furthermore, the power consumption and the difficulty in cleaning for a colour change remain high. Mills of the closed type commercially known under the name "Netzsch" are also used, in which the rotor and the grinding chamber are provided with respective pluralities of dowels.

Said mills, which are capable of subjecting the mixture to a good shearing effect and accommodate in their interior a limited amount of mixture and of grinding means, require however high power and furthermore have high constructive complication, with the well-known disadvantages which are unavoidably associated therewith; in particular the difficulty in cleaning remains unchanged.

A defect shared by all the vertical microsphere mills currently available on the market is furthermore constituted by the poor distribution of the grinding means within the grinding chamber during the operation of the machine. This disadvantage is very marked in the mills of the "Chicago Boiler" and "Vollrath" types. In fact, by inspecting the static part of such machines, that is to say the interior of the grinding chamber, grooves are observed at the impellers, due to the abrasion exerted by the grinding means, along the entire perimeter of the chamber. Such grooves are deeper at the first impellers and gradually more superficial at the central impellers until they are practically negligible at the upper impellers. A similar inspection carried out on the rotating parts of such machines has pointed out heavy wears of the thickness of the impellers, heaviest for the first impeller, decreasing up to the central impellers and practically negligible for the upper impellers. The rotor shaft bearing the impellers also has similar wears, high in the lower part and practically negligible in the upper half, and this indicates that during processing said shaft is affected by the grinding means. To conclude, during grinding, the grinding means tends to occupy the lower half of the grinding chamber with a distribution of the concentration decreasing from the bottom upwards also affecting the rotor shaft.

Such a distribution, besides considerably reducing the efficiency of the machine, causes local overheatings, harmful for the painting products, excessive wears of the main elements of the machine, difficulty in cleaning. In more recently designed mills, also with cylindrical grinding chamber and with impellers with equal dimensions and shape, equally spaced along the rotor, the distribution of the grinding means has a parabolic path with negative origin. Even for these mills the same disadvantages described above are observed, though in a less marked manner. It has in fact been experimentally verified that, the type of mill being set in terms of capacity, the amount and the type of grinding means (for example glass spheres with one-millimeter diameter), the type of mixture (specific weight, viscosity), there exists one, and only one, value of the flow-rate for which parabolic distribution, with negative origin, of the grinding means occurs. For flow-rate values different from the optimum one, these machines have a behaviour fully similar to those previously mentioned. This because, since the impellers are equal in diameter and thickness, in each point, along the entire grinding chamber, the same value of centrifugal acceleration is provided. Therefore, considering a particle between two impellers, the same is always subject to equal and opposite forces and can therefore rise along the grinding chamber until its weight force balances the vertical component of the centrifugal acceleration.

In these conditions the only parameter which intervenes to change the distribution of the grinding means is the feed flow-rate and, conditions being equal, there exists indeed one and only one flow-rate value suitable to cause a parabolic distribution with negative origin.

An important object of the present invention is to eliminate the disadvantages described above, peculiar to known vertical microsphere mills.

An object of the present invention is to provide a vertical microsphere mill with significantly improved efficiency. For this purpose, the present invention is based on the observation that the kinetic factor responsible for the distribution of the grinding means, and therefore for the efficiency of the machine, is not peripheral speed, as supposed hitherto, but centrifugal acceleration, which is a function, as well as of the peripheral speed, also of the dimensions of the rotating elements.

For the efficiency of the machine, the dimensions of the so-called expansion volume, that is to say the portion of volume of the grinding chamber overlying the last impeller, have also turned out to be important.

To eliminate the above described disadvantages and at the same time significantly improve the efficiency of the machine, the present invention provides a vertical microsphere mill with a grinding chamber and a rotor rotatably mounted in said chamber, the essential characteristic whereof resides in that fact that said grinding chamber is in the shape of a truncated cone with circular cross section and in that therotor comprises a plurality of disc-like impellers, having differentiated diameters and thicknesses decreasing along the axis of the grinding chamber, generating a truncated-cone rotor profile orientated similarly to the truncated-cone profile of the grinding chamber but with lower conicity with respect thereto; the impellers being mutually separated by spacers having an active profile to cooperate with said impellers for grinding and to prevent the accumulation of material.

Advantageously, the conicity angle of the grinding chamber is chosen equal to 9° and that of the truncated-cone profile generated by the rotor impellers is chosen equal to 6°. The greater conicity of the grinding chamber with respect to that of the profile generated by the impellers of the rotor favours the penetration of the grinding means therebetween.

Another characteristic of the mill according to the invention resides in the fact that the grinding chamber has an expansion volume the capacity whereof is equal to 5.25% of the capacity of the grinding chamber.

A further characteristic of the mill according to the invention resides in the fact that the difference between the mean internal radius of the grinding chamber and the mean outer radius of the truncated-cone profile generated by the disc-like impellers is equal to 1.6 times the mean thickness of said impellers and in that the spacers spacing the impellers have an axial extension equal to 3.3 times the means thickness s of the impellers.

Further characteristics, purposes and advantages of the invention will become apparent from the following detailed description, given only by way of non-limitative example, and illustrated in the accompanying drawings, wherein:

figure 1 is an axial sectional view of the mill according to the invention,

figure 2 is an enlarged-scale detail of figure 1,

figure 3 is another enlarged-scale detail of figure 1.

In the figures, 1 generally indicates the mill which comprises a truncated-cone casing 2, having the axis x-x arranged vertically, downwardly closed by a bottom 3 connected to the casing 2 by means of screws 7; the bottom 3 being provided with a cooling interspace 4 and with a discharge 5 for the grinding means.

At the bottom 3, in the casing 2, there is formed an inlet opening 8 through which there is continuously introduced a mixture of pigment and fluid medium into the grinding chamber 12 - as indicated by the arrow F.

The casing 2 is formed by a first wall 12 delimiting the grinding chamber 12 and by an outer skin 13A delimiting, with the wall 13, an interspace 14.

In the interspace 14 there is inserted a helical partition 15 which defines a helical path 16 extending along the casing between the end openings 17 and 18 provided in the outer skin 13A and provided with respective connections 19 and 20. A cooling fluid, for example water, flows through the helical path 16. An inlet 21, passing through the wall 13 and the skin 13A, allows to load the grinding means into the chamber 12; the closure of the inlet being effected by means of a piston 22. The grinding chamber 12 defined within the casing 2 is in the shape of a truncated cone and extends between the bottom 3 and a discharge section U at which there is defined an expansion volume 12A. The volume of said chamber represents, subtracting the expansion volume 12A, the capacity of the mill; the expansion volume being equal to 5.5% of the overall volume of the chamber 12. In the chamber 12 there is rotatably mounted a rotor 31 the axis of rotation x-x whereof coincides with the axis of the casing 2. The rotor 31 has its lower end 38 free and positioned at a small distance from the bottom 3, the upper opposite end 38A being axially and torsionally coupled to a shaft 40 rotatably supported by a guiding dome 39 by means of conventional rolling bearings.

The shaft 40 of the rotor protrudes outside the discharge section U, and is intended to be connected, in a fully known manner, to motor means, not illustrated, for the rotary actuation of the rotor 31, at a set angular speed which will be described hereinafter.

The rotor 31 is provided with a plurality of impellers 41 spaced by an axial pitch d and separated by shaped spacers 42. A plurality of tension rods 43 connects said impellers 41 and said spacers 42 to one another, as well as to an upper hub 50 of the rotor torsionally connected to the shaft 40 by means of a key 32.

Given:

R1 = mean internal radius of the grinding chamber

R2 = mean outer radius of the impellers 41 of the rotor

s = mean thickness of the impellers 41

d = axial pitch of the impellers 41

H = height of the grinding chamber 12,

the following dimensional relationships must be verified

R1 - R2 = 1.6 s

d = 3.3 s

H = 7.2 R1

Furthermore, the conicity of the wall 13 defining the grinding chamber is preferably comprised between 8 and 10° and is advantageously chosen equal to 9° and the conicity of the truncated-cone profile generated by the impellers is comprised between 5° and 7°, advantageously 6°.

By way of example the characteristic dimensions of a mill according to the invention, with a capacity equal to 12 liters and actuated by a 7.5 KW motor, are given hereinafter:

- Grinding chamber height = 583 mm
- Maximum diameter of grinding chamber = 175 mm
- Minimum diameter of grinding chamber = 150 mm
- Number of impellers = 16
- Maximum diameter of impellers = 145 mm
- Minimum diameter of impellers = 130 mm
- Maximum thickness of impellers = 7.8 mm
- Minimum thickness of impellers = 6.4 mm
- Number of shaped spacers = 15+1
- Maximum diameter of shaped spacers = 120 mm
- Minimum diameter of shaped spacers = 90 mm

- Maximum thickness of shaped spacers = 23 mm
- Minimum thickness of shaped spacers = 23 mm

The mill at issue furthermore has the following conditions which are important for high efficiency:

a) peripheral speed of the impellers greater then, or equal to, 6 m/sec,

b) centrifugal acceleration comprised between 1600 and 1450 m/sec^2.

It has in fact been observed that the abovementioned speed and acceleration values represent, respectively the minimum threshold below which the efficiency rapidly decreases and the optimum values for a correct distribution of the material being processed within the grinding chamber. In terms of the efficiency of the machine it is also important to appropriately set the volume of the grinding means (for example microspheres) which must be comprised between 25 and 30% of the capacity of the mill.

As is clearly demonstrated in figure 1, the shaped spacers 42 have a substantially sinusoidal active profile 42A with a central peak and two lateral saddles connecting to each of two consecutive impellers 41. This particular configuration, while on one hand it prevents the accumulation of residuals in the spaces immediately adjacent to the impellers (absence of dead corners), on the other hand imparts to the spacer, an effect similar to that of the impellers though with lesser intensity by virtue of the presence of the central peaked portion; the contribution of the spacers in terms of centrifugal acceleration being approximately 20% lower than that of the impellers.

By adopting spacers 42 as described, the machine becomes self-cleaning, allowing the elimination of the expensive and laborious colour changing operations necessary with known machines.

For the self-cleaning behaviour, the structure of the earlier mentioned discharge section U is also fundamental.

According to the present invention the discharge section U comprises a static part and a rotating part. The static part is formed by a closure lid 23 fixed to the casing 2 with brackets 24 and screws 25. In the like 23 there is accommodated a static truncated-cone segment 26 which extends in a cylindrical seat 27 intended to accommodate the rings 27A for the radial sealing of the passage of the shaft 40. A cooling chamber 28 encircles the static segment 26 in which there is also formed the connection 29 for the discharge of the treated product. The rotating part of the discharge section U is constituted by a blade impeller 30 keyed on the shaft 40 by means of the key 32 and contained in the cavity of the static segment 26. On its lower face the impeller has a sealing and centering segment 33 locked by a flange 34 and by screws 35.

Advantageously, according to the invention at least the characteristic elements of the rotor such as the impellers 41 and the spacers 42 are in polymeric material known under the trade-name "Nylon".

According to the stated aim and objects, the mill according to the invention has shown an effective shearing action of the pigment-fluid medium mixture, greater than that of known mills and this essentially by virtue of the action of the impellers which adds to that of the shaped spacers, leading to a rapid dispersion of the former in the latter; the combination of grinding means and mixture being entirely located at the periphery of the rotor, where the peripheral speeds are highest.

Furthermore, the mill according to the invention has been shown to have, for equal chemical-physical characteristics of the treated product, considerably reduced dimensions, with evident economical advantages, and a power approximately 20% lower than that of equivalent-capacity known mills has been found necessary for its actuation.

Naturally, the concept of the invention remaining invariant, the details of execution and the embodiments may be extensively variated, with respect to what is described and illustrated by way of non-limitative example, without thereby abandoning the scope of the invention.

Where technical features mentioned in any claim are followed by reference signs, those reference signs have been included for the sole purpose of increasing the intelligibility of the claims and accordingly, such reference signs do not have any limiting effect on the scope of each element identified by way of example by such reference signs.

Claims

1. Vertical microsphere mill of the type comprising a grinding chamber (12) and a rotor (31) rotatably mounted in said chamber to disperse a pigment in a fluid medium by means of a grinding means such as microspheres, sand and the like, characterized in that said grinding chamber (12) is in the shape of a truncated cone with circular cross section and in that said rotor (31) comprises a plurality of disc-like impellers (41), having differentiated diameters and thicknesses decreasing along the axis of the grinding chamber, generating a truncated-cone rotor profile orientated similarly to the truncated-cone profile of the grinding chamber but with lower conicity with respect thereto; the impellers being mutually separated by spacers (42) having an active profile (42A) to cooperate with said impellers for grinding.

2. Vertical mill according to claim 1, characterized in that the conicity angle of the grinding chamber (12) is chosen equal to 9° and the conicity angle of the truncated-cone profile generated by the rotor impellers (41) is chosen equal to 6°.

3. Vertical mill according to claims 1 and 2, characterized in that the mean average radius (R1) of the grinding chamber (12), the means radius (R2) of the truncated-cone profile generated by the impellers (41) of the rotor (31), the mean thickness (s) of said impellers (41) and the axial extension (d) of the spacers (42) interposed between the impellers (41) satisfy the following dimensional relationships:

$R1 - R2 = 1.6s$

$d = 3.3s$

4. Vertical mill according to one or more of the preceding claims, characterized in that the height (H) of the expansion chamber and its mean radius (R1) are in the following dimensional ratio: $H/R1 = 7.2$.

5. Vertical mill according to one or more of the preceding claims, characterized in that the peripheral speed of the disc-like rotor impeller having minimum radius is greater than, or equal to, 6 m/sec^2.

6. Vertical mill according to one or more of the preceding claims, characterized in that the centrifugal acceleration of the rotor impellers is comprised between 1600 and 1450 m/sec and varies in a linear manner along the axis of rotation.

7. Vertical mill according to the one or more of the preceding claims, characterized in that the grinding chamber comprises an expansion volume equal to 5.5% of the total volume of the chamber.

8. Vertical mill according to one or more of the preceding claims, characterized in that the spacers (42) interposed between the impellers (41) of the rotor (31) have a substantially sinusoidal active profile (42A) with a central peak and two lateral saddles connecting to each of two consecutive impellers (41); the radial dimensions of said spacers being chosen so that the contribution thereof in terms of centrifugal aceleration is 20÷25% smaller than that of the impellers.

9. Vertical mill according to one or more of the preceding claims, characterized in that at least said impellers and said spacers of the rotor are of material known under the trade-name "Nylon".

10. Vertical mill according to one or more of the precedign claims, characterized in that the grinding chamber (12) is delimited in a casing (2) comprising an inner wall (13) and an outer skin (13A) forming an interspace (14) in which, by means of a helical partition, there is defined a corresponding helical path (16) for a cooling fluid.

11. Vertical mill according to the preceding claim, characterized in that said casing (2) is downwardly closed by a bottom (3) provided with a cooling interspace (4).

12. Vertical mill according to one or more of the precedign claims, characterized in that said grinding chamber (12) upwardly ends with a discharge section (U) comprising a static part and a rotating part, in that the static part comprises a lid (23), connected to the casing delimiting the grinding chamber (12), in which there is accommodated a static truncated-cone segment (26) bearing the seats (27) of the sealing rings (27A) for the rotor shaft (40) and the connection (29) for the discharge of the treated product; said static segment (26) being encircled by a cooling chamber (28); and in that the rotating part is constituted by a blade impeller (30) keyed on the rotor shaft (40) and contained in the cavity of said truncated-cone static segment (26).

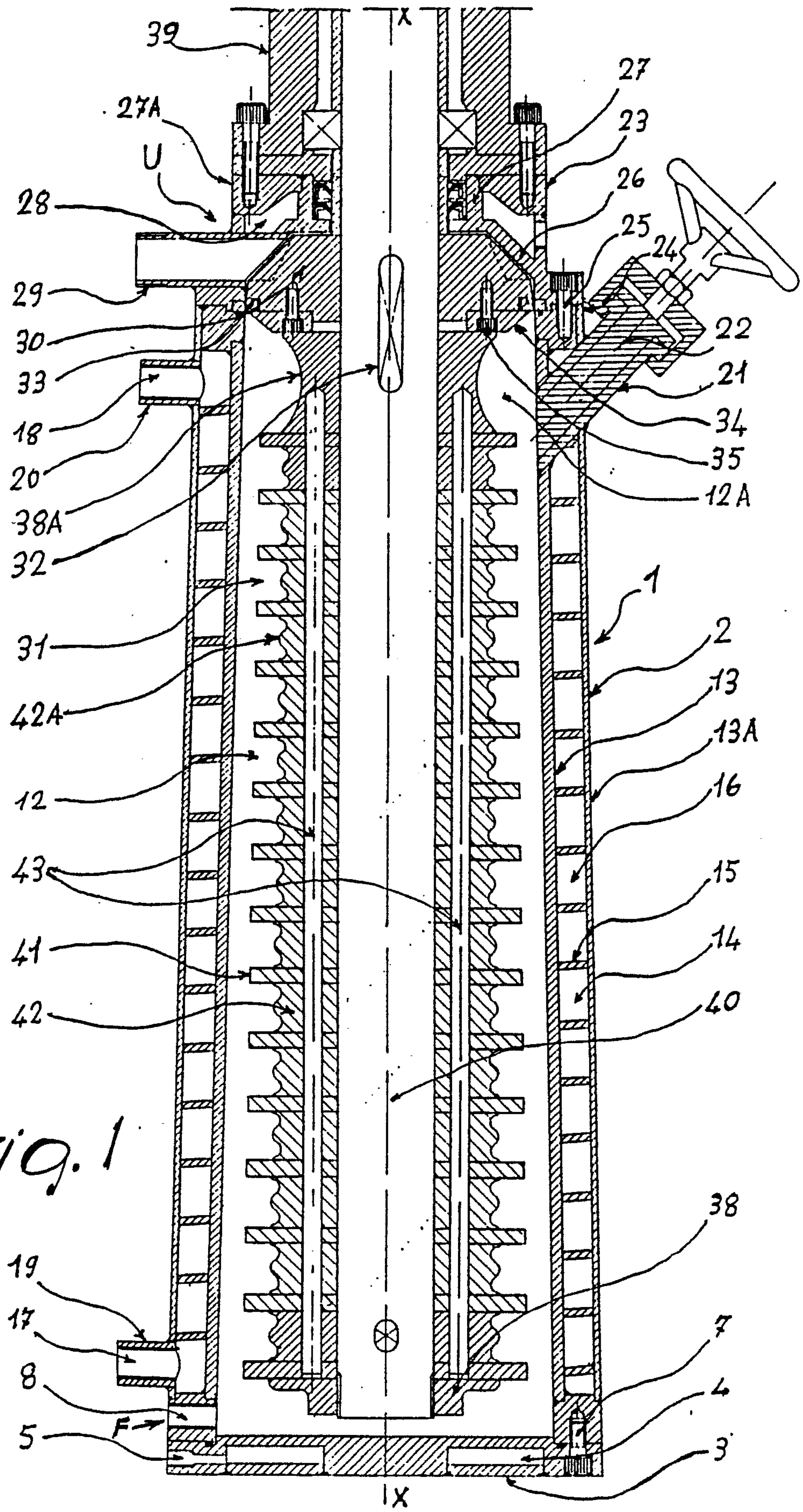
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Fig. 1

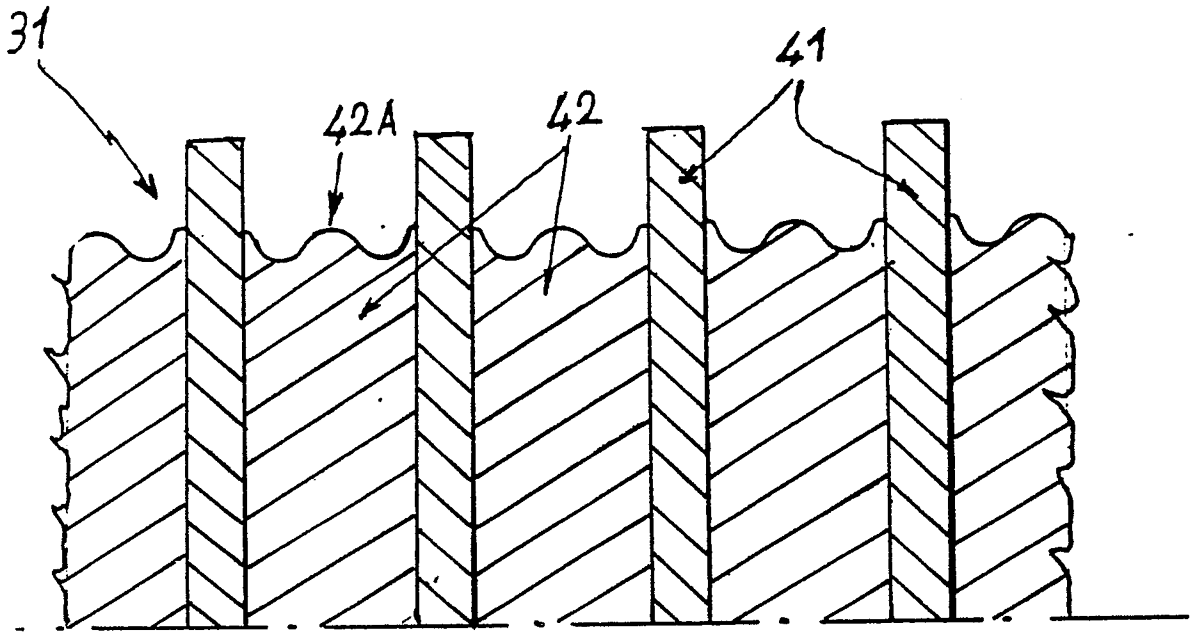

Fig.2

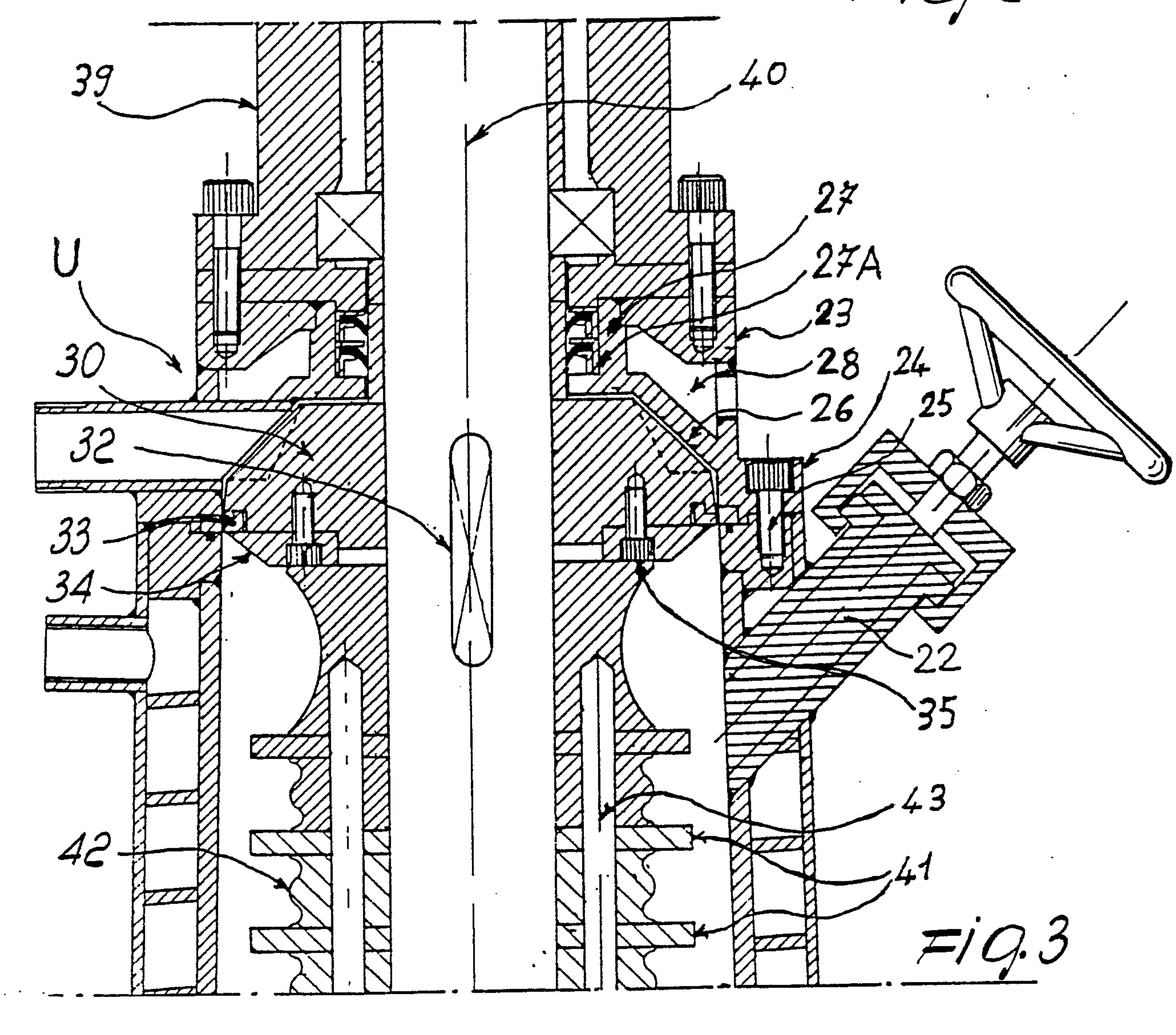

Fig.3