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Krämer
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[54] **HYDRAULIC CONVEYING APPARATUS**

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[30] **Foreign Application Priority Data**

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Mar. 11, 1972 Germany 2211786

[52] **U.S. Cl.** .... **418/96,** 418/152, 418/175, 418/177, 418/180, 418/209, 418/210, 418/255, 418/258, 418/269, 192/58 R

[51] **Int. Cl.** **F01c 1/00,** F03c 3/00, F04c 1/00

[58] **Field of Search** .... 418/68, 96, 152, 175, 177, 418/180, 209, 210, 254, 255, 258, 269, 270; 192/58 R

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Primary Examiner—Carlton R. Croyle
Assistant Examiner—John J. Vrablik
Attorney, Agent, or Firm—Michael S. Striker

[57] **ABSTRACT**

An elongated housing is formed with an axial passage therethrough the surface of which is defined by a helical screw surface. A cylindrical support member with a cross section smaller than that of the passage extends through the latter and engages the surface along a helical line. The support member is formed with a transverse slot therethrough in which a plurality of closely adjacent narrow sealing elements are guided movable in direction transverse to the axis of the support member and engaging with outer ends the passage surface so that during rotation of the support member and the housing relative to each other, a fluid entering the housing at one end may be pumped under pressure through an outlet at the other end of the housing. On the other hand, the arrangement may also be used as a fluid transmission by transmitting a drive to the housing and taking up the drive from the support member, or vice versa.

38 Claims, 23 Drawing Figures

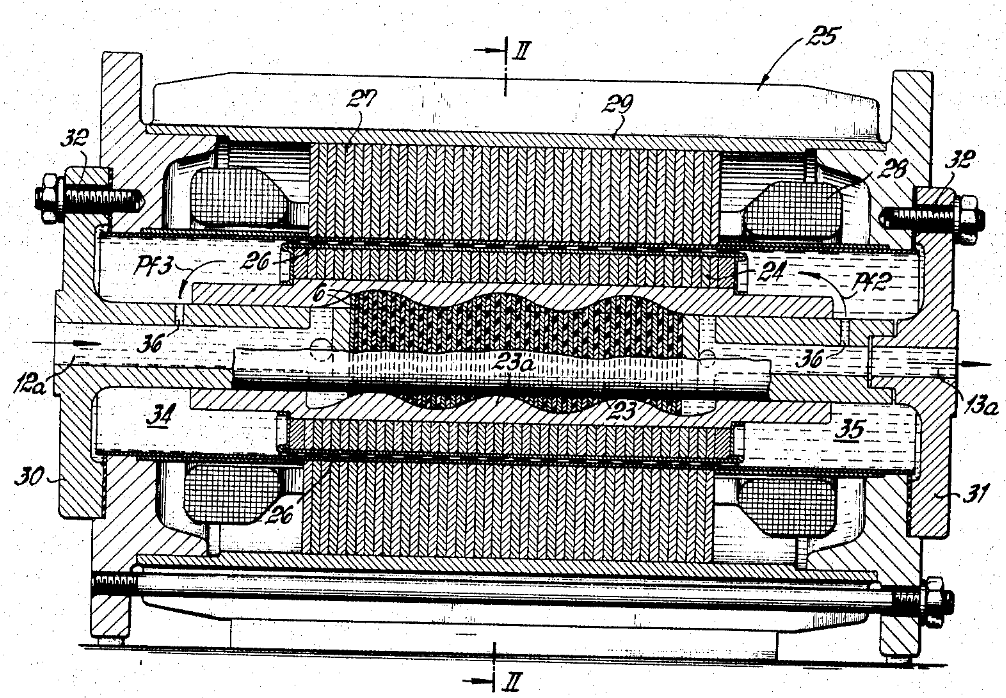
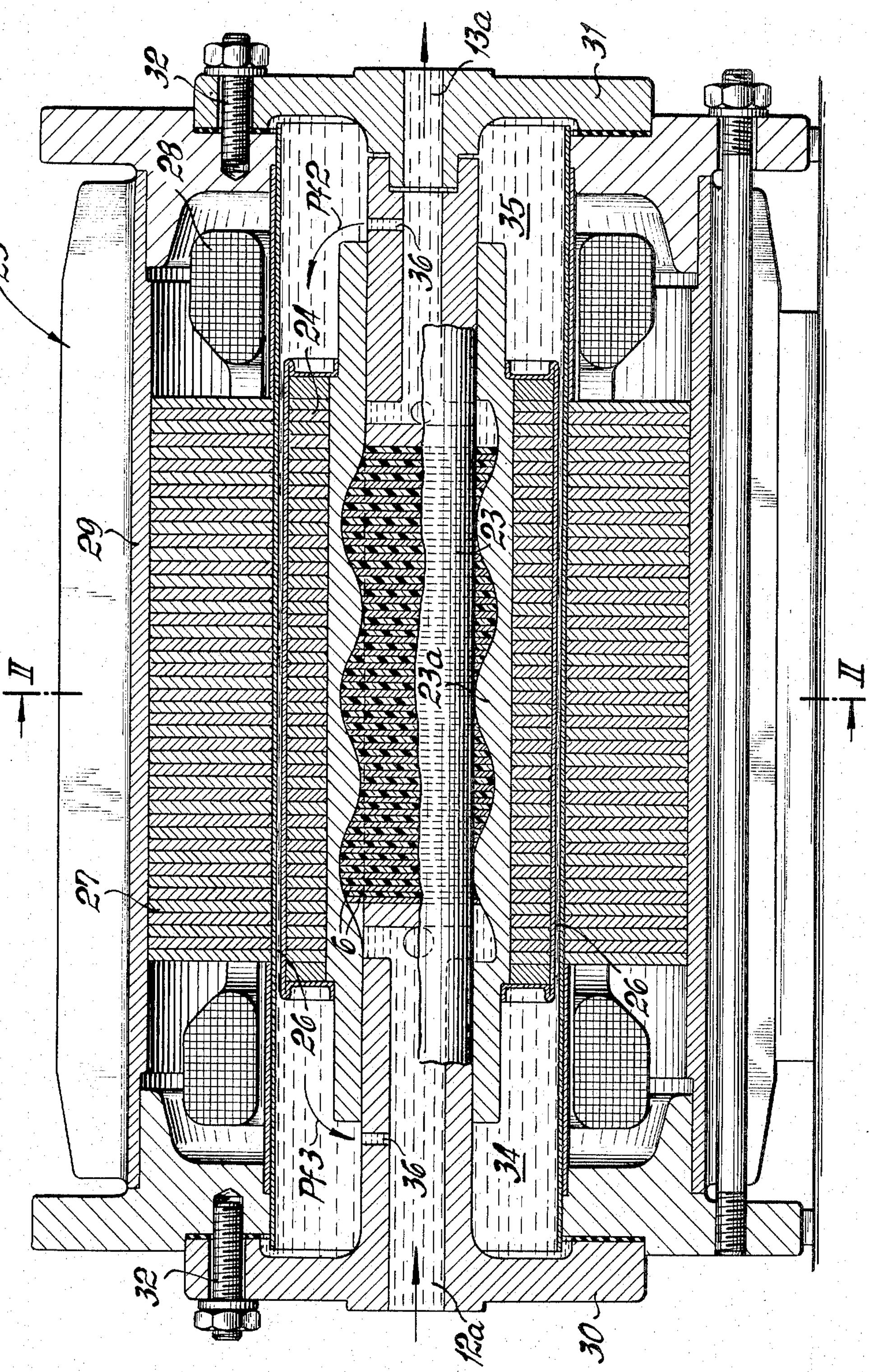


FIG.1


13a
31
32
28
25
35
36
Pf2
24
29
23
23a
II
II
27
6
26
26
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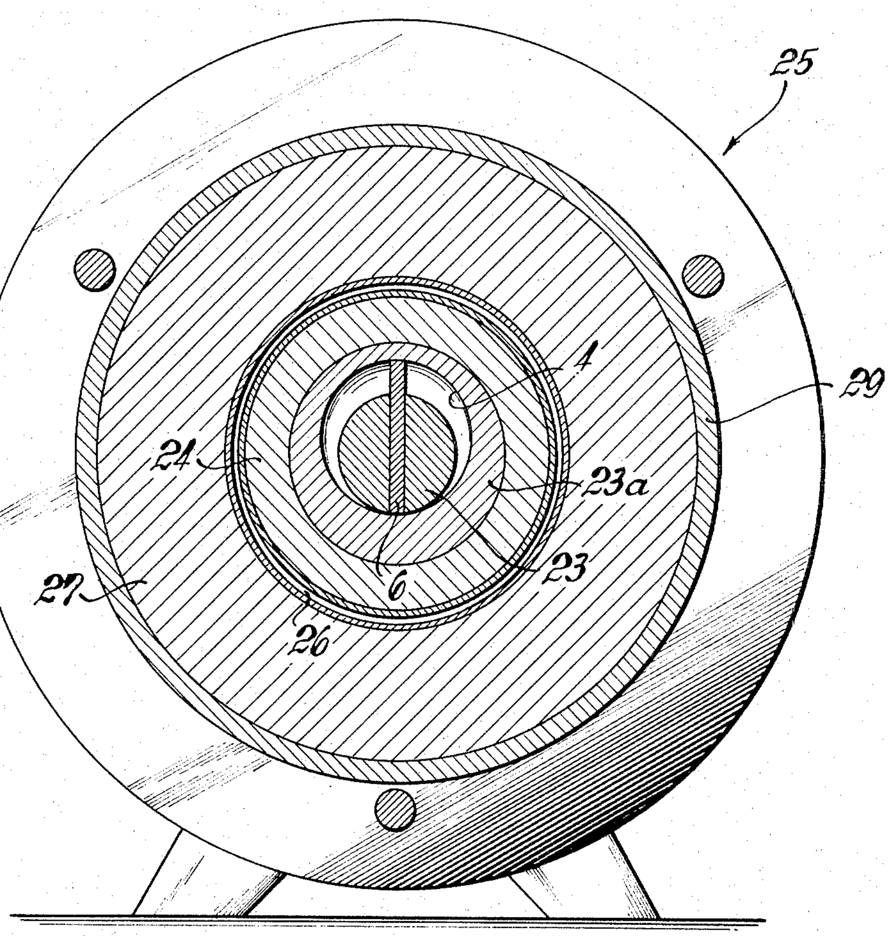
Pf3
36
32
12a
30

FIG. 2



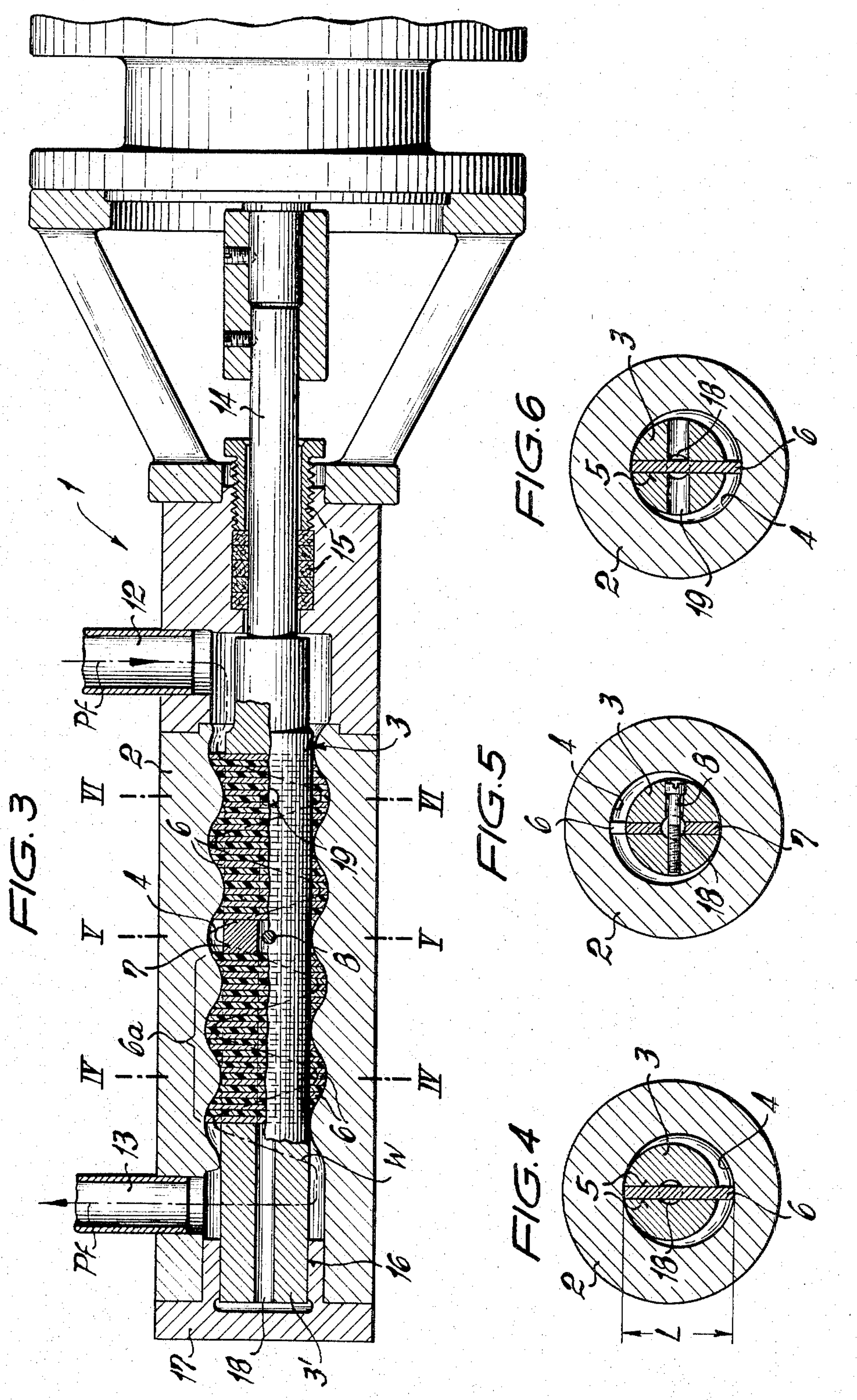


FIG. 3

FIG. 4

FIG. 5

FIG. 6

FIG. 7

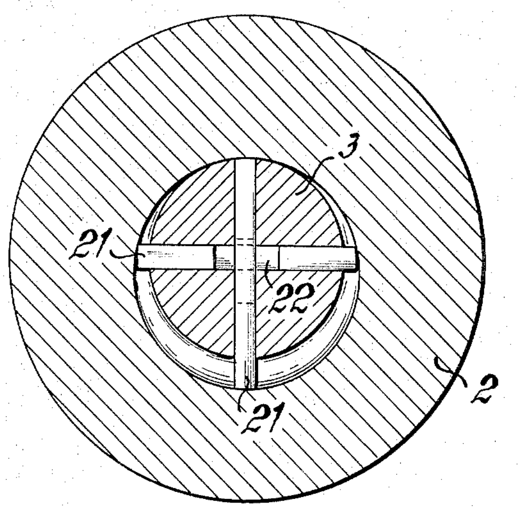


FIG. 8

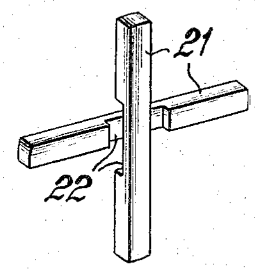


FIG. 11

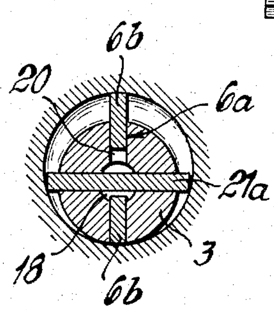
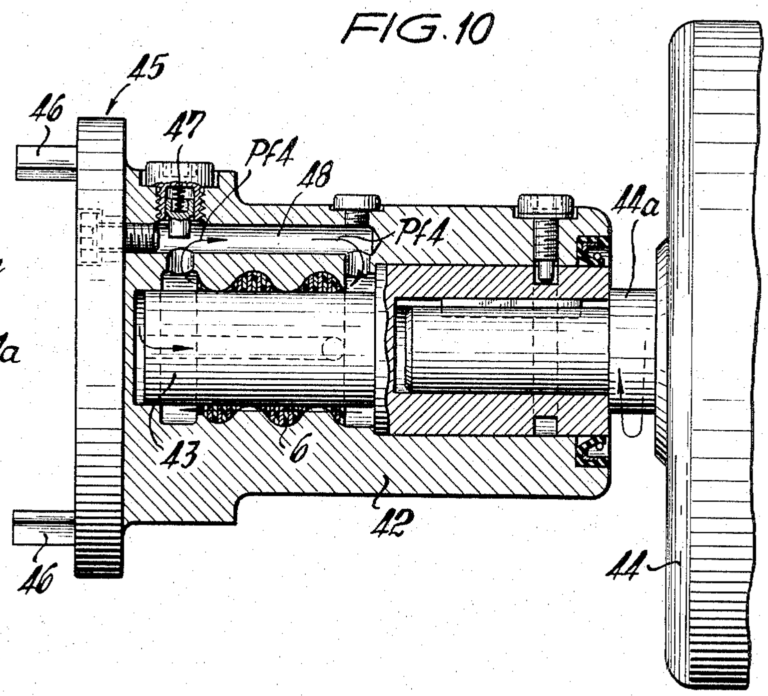


FIG. 10



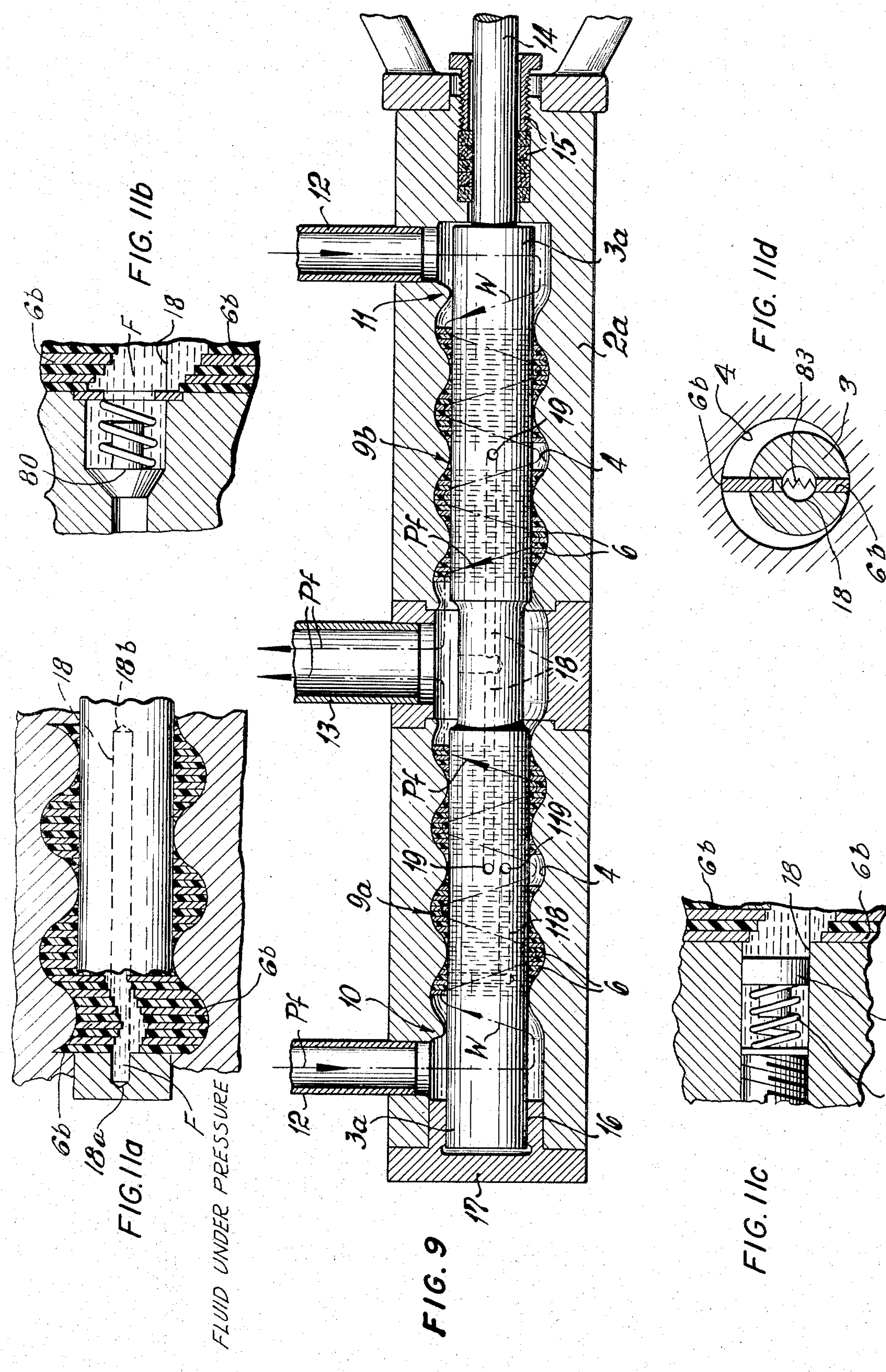


FIG. 11b
6b
F
18
6b
80
FIG. 11a
18
18b
6b
6b
18a
F
FLUID UNDER PRESSURE
FIG. 9
14
15
12
3a
11
W
2a
9b
19
4
Pf
6
Pf
13
18
Pf
149
19
9a
4
118
6
10
Pf
W
12
3a
16
17
FIG. 11d
6b
4
83
3
6b
18
FIG. 11c
6b
18
6b
81
82

FIG. 12

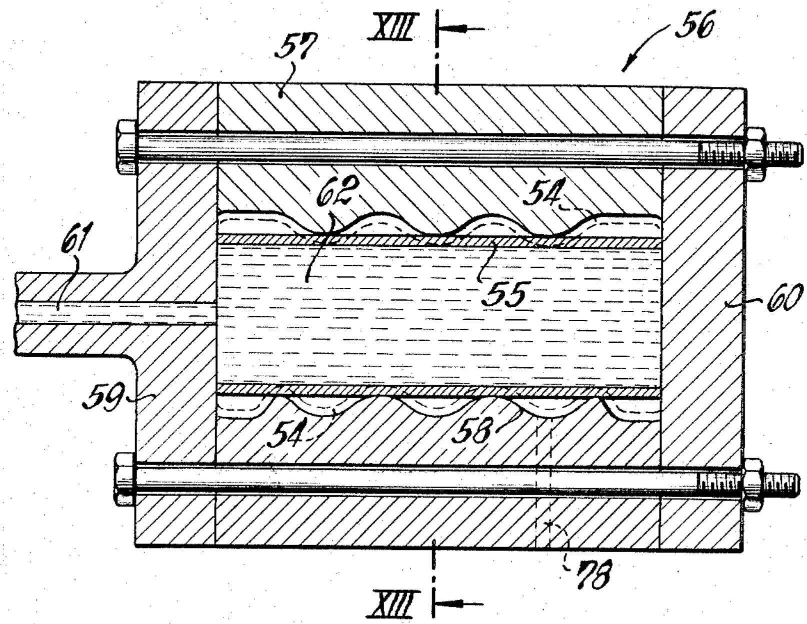
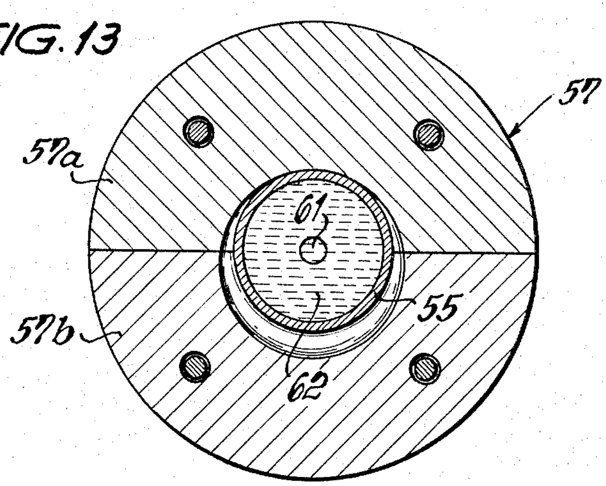


FIG. 13



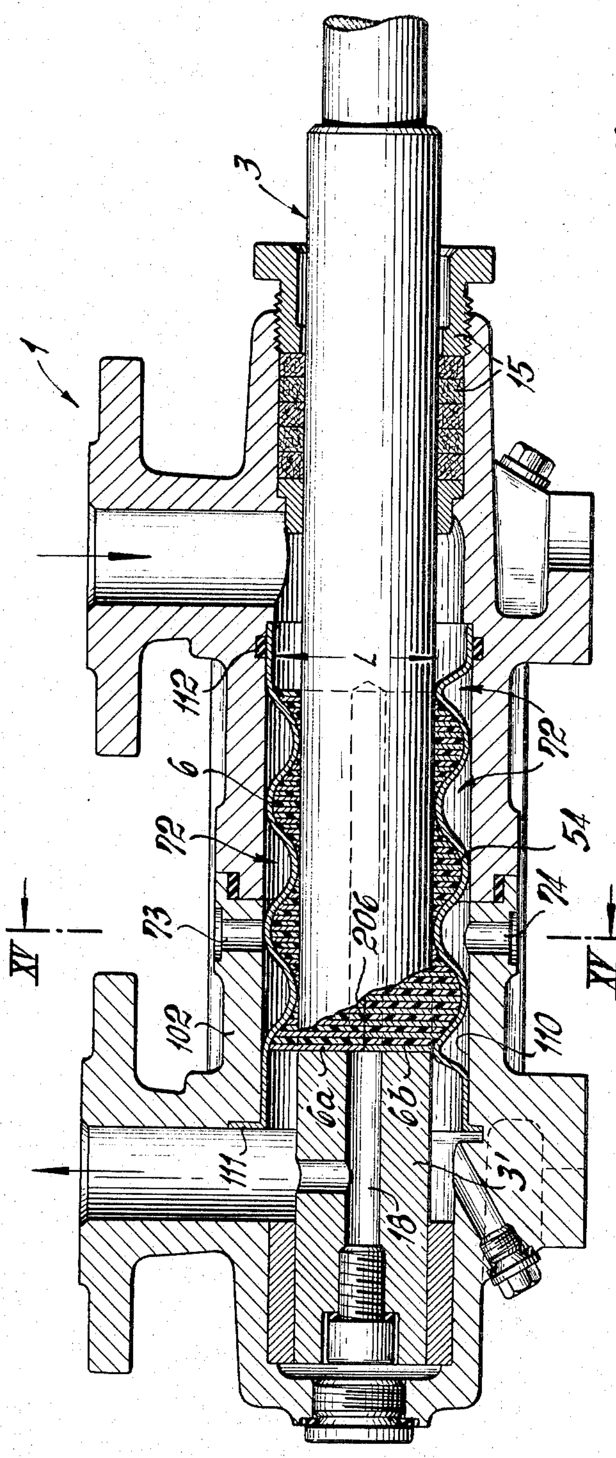


FIG. 14

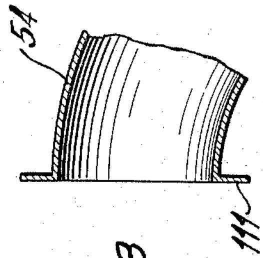


FIG. 18

FIG. 15

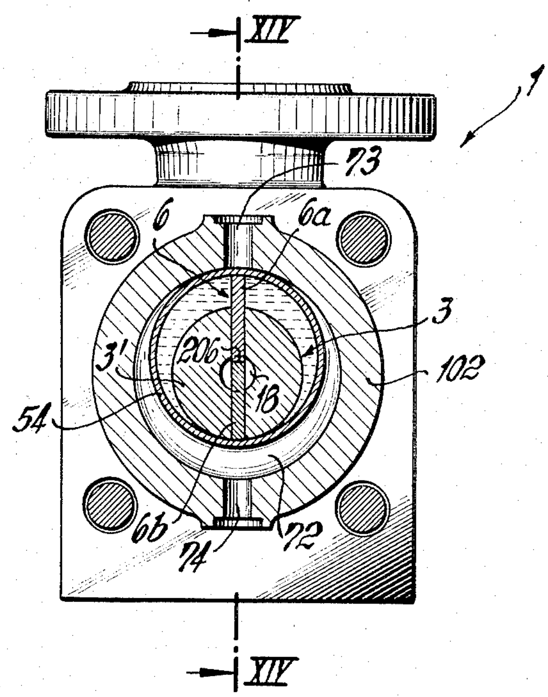
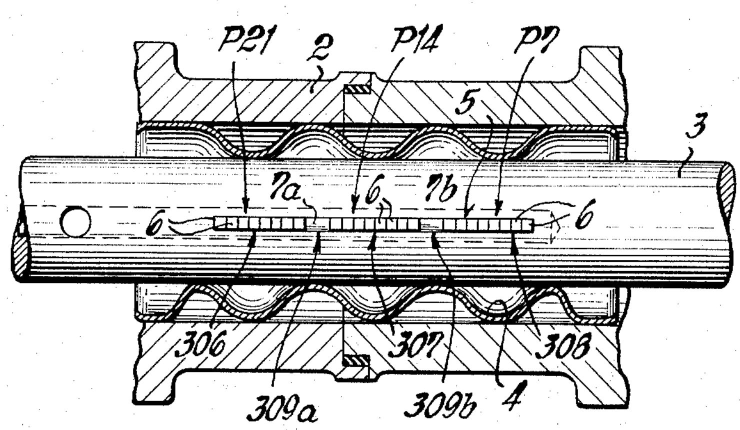

XIV
1
73
6
6a
3
3'
206
18
102
54
6b
74
72
XIV

FIG. 19


P21
2
P14
P7
5
3
7a
6
7b
6
6
306
307
308
309a
309b
4

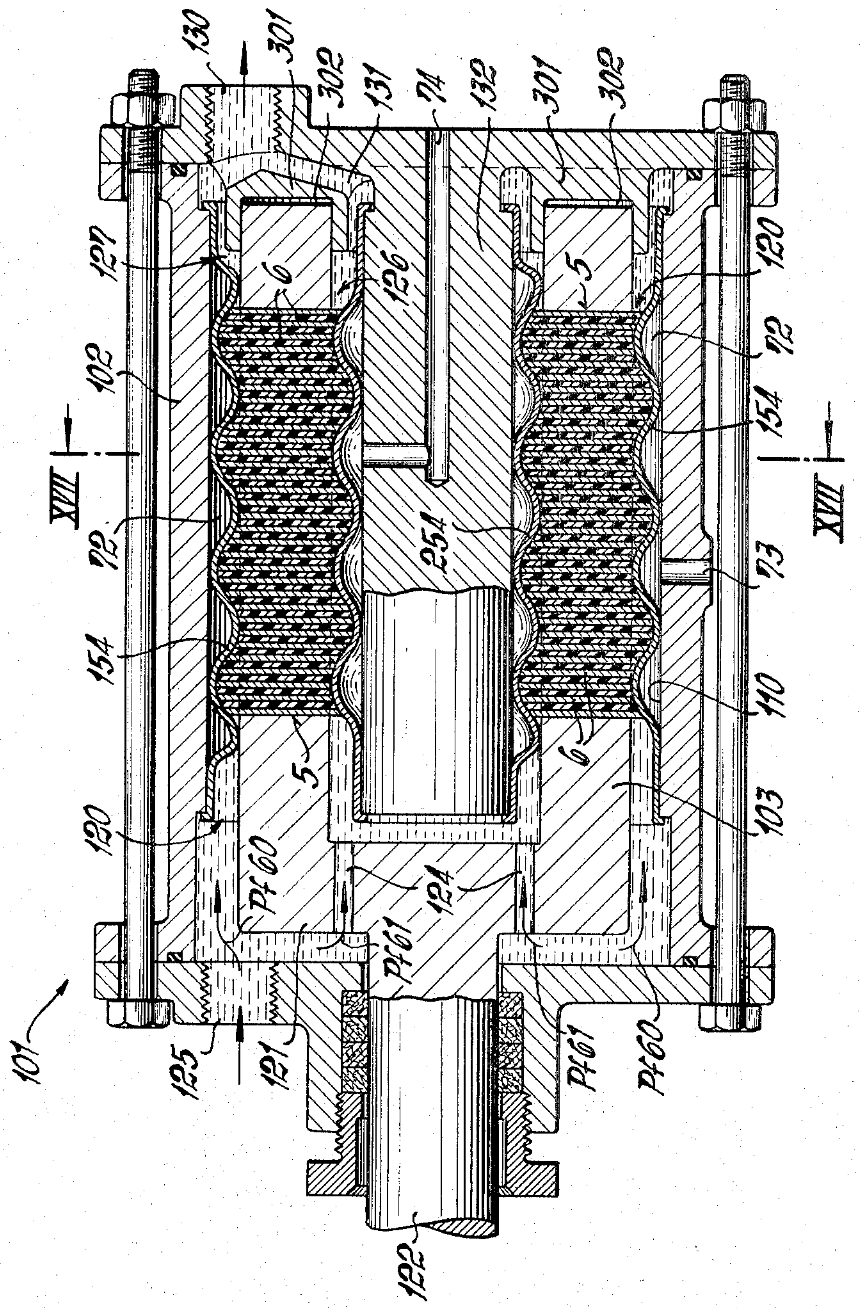
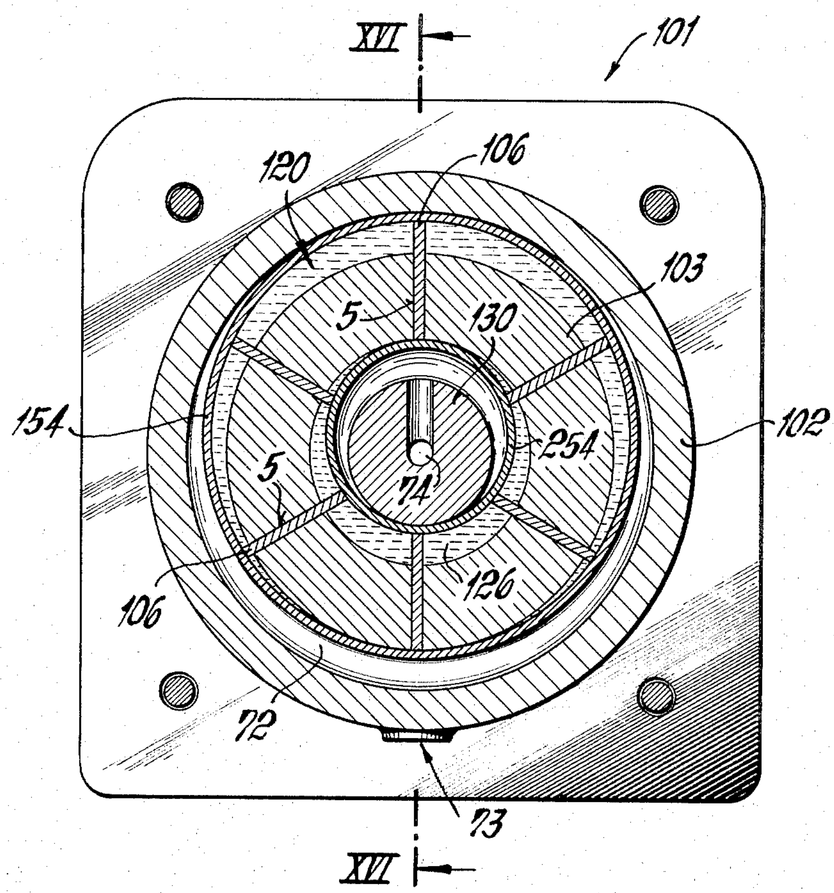

130
301
302
131
74
132
301
302
127
6
126
5
120
72
102
154
XVIII
72
254
73
154
110
6
5
103
120
Pf 60
Pf 61
124
101
125
121
Pf 61
Pf 60
122

FIG. 16

FIG. 17



HYDRAULIC CONVEYING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an hydraulic conveying apparatus, especially a pump, having a pump housing and a rotor located therein, whereby during rotation of the rotor and the housing relative to each other a flowable medium may be conveyed in axial direction through the housing.

Such pumps are known in the art and usually comprise a rotor with acute blades fixed thereto located in the interior of a hollow housing which during turning of the rotor will pump a medium in axial direction through the housing. Such pumps have to operate with relatively high speed and are adapted only for pumping liquids having a viscosity substantially equal to the viscosity of water. Such pumps are however unsuitable for pumping liquids which contain granulated material such as mud, sand or pasty concrete mix and similar materials.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an hydraulic conveying apparatus, especially a pump, which overcomes the disadvantages of such pumps known in the art.

More specifically, it is an object of the present invention to provide for a conveying apparatus of the aforementioned type which cannot only convey liquids of low viscosity, but also pasty materials or even solid finely granulated materials. The conveying apparatus should further be constructed in such a manner that it can also efficiently be operated at a slow speed, especially during conveying of liquids of high viscosity or during conveying of granulated material such as nuts, beans or the like or mixtures of liquid and solid material, as for instance small fruits suspended in juice, motar and cement before the same are hardened. In addition, the conveying apparatus should be constructed in such a manner that, especially if it serves as pump for liquids, relatively high conveying pressures can be obtained.

It is a further object of the present invention to provide a conveying apparatus of the aforementioned type which is constructed of relatively few and simple components so that the apparatus may be built at reasonable cost and stand up perfectly under extended use.

With these and other objects in view, which will become apparent as the description proceeds, the conveying apparatus according to the present invention mainly comprises an elongated housing having an axis being formed with an axial passage therethrough defined by a helical screw surface, substantially cylindrical support means extending in the direction of the axis through the passage and having a cross section smaller than that of the passage and being arranged in the latter so as to engage the aforementioned surface substantially tangentially along a helical line, and a plurality of sealing elements mounted on the support means, extending diagonally through the passage and engaging the aforementioned surface. The plurality of sealing elements are arranged closely adjacent to each other in the direction of the axis and being movable relative to each other in a direction transverse to the axis. Each of the sealing elements has a width in the direction of the axis which is considerably smaller than the pitch of the screw surface.

During rotation of the cylindrical support means relative to the housing, the sealing elements will slide with the outer ends thereof along the surface defining the passage through the housing. Since the passage through the housing is defined by a helical screw surface, and every cross section of this passage is eccentrically arranged with regard to the cylindrical support means, there will result a to and fro movement of the sealing elements in direction transverse to the housing axis during rotation of the cylindrical support means and the sealing elements thereon with respect to the housing. A liquid or a similar medium located in the passage is thereby conveyed in axial direction of the latter during rotation of the cylindrical support means and the sealing elements thereon due to the screw configuration of the inner surface of the housing. Due to the rotation of the rotor constituted by the support means and the sealing elements and the sealing of the rotor with respect to the surrounding housing along an axial line, the medium to be conveyed is so to speak "forwardly screwed" through the housing. In advantageous manner, the sealing elements will seal each housing cross section at two opposite points since the sealing elements will sealingly engage with the outer ends thereof the surface of the passage through the housing. An additional advantage of the construction is that the movement of the sealing elements is positively controlled by the configuration of the passage through the housing.

If the helical screw surface which defines the passage through the housing extends only through a part of a single convolution of the helix, a small conveying pressure will result, which can however be increased by extending the helical screw surface through a plurality of convolutions. Due to the positive control of the movement of the sealing elements it is possible to operate such a pump in advantageous manner at relatively low speed while still obtaining a continuous conveying of the medium passing therethrough. In this way it is possible to use the conveying apparatus not only to pump liquids but also to convey granulated material or a mixture of liquids and solid bodies.

An additional advantage of the conveying apparatus according to the present invention is that the inlet and outlet of the conveying apparatus can be chosen at will, depending on the direction of rotation of the cylindrical support means relative to the housing, whereby when the direction of the rotation is changed, the flow direction of the medium through the housing will be reversed and the inlet will become the outlet and vice versa.

The novel features which are considered as characteristic of the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its mode of operation, together with additional features and advantages thereof, will be best understood upon perusal of the following detailed description of certain specific embodiments with reference to the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an axial cross section through an hydraulic conveying apparatus according to the present invention in which a relative movement between the housing and the cylindrical support means carrying the sealing elements is obtained by rotating the housing which in this case forms part of the rotor of an electrical motor;

FIG. 2 is a cross section along the line II—II of FIG. 1;

FIG. 3 is a longitudinal cross section through another conveying apparatus in which the relative movement between the housing and the cylindrical support means carrying the sealing elements is carried out by rotating the support means with the sealing elements relative to the stationarily held housing;

FIG. 4 is a cross section taken along the line IV—IV of FIG. 3;

FIG. 5 is a cross section taken along the line V—V in FIG. 3;

FIG. 6 is a cross section taken along the line VI—VI of FIG. 3;

FIG. 7 is a transverse cross section of a modified construction in which the sealing elements cross each other;

FIG. 8 is a perspective view showing the construction of two crossing sealing elements;

FIG. 9 is an axial cross section through a further modification and illustrating a conveying apparatus in which the housing is formed with two oppositely convoluted helical screw surfaces;

FIG. 10 is an axial cross section through a further modification in which the housing as well as the cylindrical support means with the sealing elements thereon are both turnably mounted so that drive of one component will result in a rotation of the other component;

FIG. 11 is a transverse section of a modification of the construction shown in FIG. 1 in which one of the crossing sealing elements is constituted by two separate parts having inner ends speced from each other;

FIG. 11*a* is an axial cross section of a modification shown in FIG. 11;

FIGS. 11*b* and 11*c* are modifications of an end portion of the construction shown in FIG. 11*a*, drawn to an enlarged scale;

FIG. 11*d* is a cross section similar to FIG. 11 and showing a further modification;

FIG. 12 is an axial cross section of a press form for manufacturing a screw bushing adapted to form the passage through a housing;

FIG. 13 is a cross section taken along the line XIII—XIII of FIG. 12;

FIG. 14 is an axial cross section through a further modification of a conveying apparatus in which the passage through the housing is constituted by a screw bushing;

FIG. 15 is a cross section taken along the line XV—XV of FIG. 14;

FIG. 16 is an axial cross section of a further modification in which the passage through the housing is an annular passage constituted by two concentrically arranged screw bushings;

FIG. 17 is a cross section taken along the line XVII—XVII of FIG. 16;

FIG. 18 is a partial axial cross section of a screw bushing with a slightly elastic connecting flange; and

FIG. 19 is a partial longitudinal cross section through a central portion of a conveying apparatus in which the sealing elements are arranged in groups spaced from each other.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawing and more specifically to FIG. 3 of the same, it will be seen that the hydraulic conveying apparatus 1 illustrated therein comprises a housing 2 formed with an axial passage therethrough, the surface 4 of which is defined by a helical screw surface constituted by a helical groove of part circular cross section, the convolutions of which are separated by correspondingly rounded ridges. In the construction illustrated in FIG. 3, the helical screw surface has about four convolutions, but evidently the aforementioned passage surface may have a greater or smaller number of convolutions. A cylindrical support member or a support means 3 extends axially through the aforementioned passage in the housing and as evident from the cross sections shown in FIGS. 4–6, the cylindrical support member 3 has a diameter which is smaller than the respective cross sections through the passage in the housing. The cylindrical support member 3' is arranged within the passage 4 in such a manner that the peripheral surface of the cylindrical support member 3' will tangentially engage the inner housing surface 4 along a helical line, whereas opposite the line of engagement, the cylindrical support member 3' is spaced at each transverse cross section from the inner housing surface 4 so that practically successive inner surface portions of the housing are eccentrically arranged with respect to the cylindrical support member 3', whereby these eccentrically arranged sections are, in axial direction of the apparatus 1, helically displaced with respect to each other.

The cylindrical support member 3' is at least in the region of the helically convoluted portion of the passage through the housing formed with an axially extending slot 5 therethrough in which a plurality of sealing elements 6, which abut with side faces thereof against each other, are arranged for movement in transverse direction to the axis of the support member 3' and which have in this transverse direction a length L which is equal to the diameter of the axial passage through the housing. The cylindrical support member 3' together with the sealing elements 6 constitute the rotor 3 of the apparatus shown in FIG. 3. The width of each sealing element in axial direction of the housing is considerably smaller and only a small fraction of the pitch of the helical screw surface defining the passage through the housing so that for each pitch of the helical screw surface a relative great number of closely adjacent sealing elements are provided which, in correspondence with the axially helically changing eccentricity of the inner surface 4 of the housing with respect to the support member 3' will be moved relative to each other in transverse direction when the rotor 3 is rotated relative to the housing. As shown in FIG. 4, each cross section of the inner surface 4 is sealed twice by the respective sealing element 6 since the latter engages with opposite ends the inner housing surface 4. This will considerably reduce any leakage losses.

During turning of the rotor 3 while the housing 2 is maintained stationarily a flowable medium between the rotor and the inner housing surface 4 will be gradually advanced in axial direction. By reversing the directional rotation of the rotor, the direction of advancement of the medium can also be reversed in a very simple manner. Evidently, it is also possible to advance the medium in axial direction by rotating the outer housing 2 about its axis while maintaining the cylinder with the sealing elements thereon stationarily as for instance shown in the modification illustrated in FIGS. 1 and 2 which will be described later on.

The sealing elements 6 are arranged parallel to each other and extend transversely through the passage of the housing substantially normal to the axis of the latter while the side faces of adjacent sealing elements engage each other. Evidently, the smaller the width of the sealing elements is, the better will be the seal obtained with respect to the surface 4, however, at the same time the friction will increase with increase of the number of the sealing elements. The width of the sealing elements has therefore to be chosen under consideration of both of the aforementioned factors.

In the specific construction illustrated in FIG. 3 the slot 5 formed through the cylindrical support member 3' is divided into two portions by an insert 7 located in a central portion of the slot and held therein by a screw 8 or the like in fixed position. As shown in the cross section of FIG. 5, the insert 7 is dimensioned to completely fill the cross section of the slot. This will reinforce the cylindrical support member 3', the strength of which is weakened by the slot therethrough, especially if the slot has a considerable length, and at the same time, the insert 7 will also provide an abutment or a thrust member for the group 6*a* of sealing elements 6 which are subjected to a certain axial force. If all sealing elements 6 of a relatively long rotor would abut only against each other, then the friction of the sealing elements produced during relative movement thereof with respect to each other might be raised to a detrimental amount.

By providing a fixed insert between two groups of sealing elements, the last sealing element as viewed in the direction of movement of the medium through the conveying apparatus of one group of seal elements will abut against the insert 7 to thereby prevent an undue increase of the total friction between the side faces of the sealing elements.

A rotor shaft 14 integral with the cylindrical support member 3' extends through a bore in one end of the housing 2. The shaft portion extending through the bore of the housing is sealed by a plurality of sealing rings 15 which are compressed by means of a bushing threaded into the housing bore. The right end, as viewed in FIG. 3, of the shaft 14 is connected by means of a coupling to a motor, only partly shown in FIG. 3, for driving the rotor. A bearing 16 is provided for the left end, as viewed in FIG. 3, of the cylindrical support member 3' and the bearing 16 is integral with a cover 17 which closes the left end of the passage through the housing. The medium inlet 12 is arranged, in the modification shown in FIG. 3, in the region of the passage of the shaft 14 through the bore in the housing so that the seal 15 is located in the region of low pressure and therefore loaded only to a limited extent. It may be advantageous to provide the cylindrical support member 3' of the rotor 3, which has a non-slotted end portion in the region of the medium outlet 13, with a central bore 18 which communicates with the region of the higher pressure in the pump and which has a diameter greater than the thickness of the sealing elements 6. As shown in the cross sections of FIGS. 4 and 5 the bore 18 has a diameter which is greater than the width of the longitudinal slot 5. This will assure that the fluid medium at high pressure in the region of the outlet 13 can pass through the clearance between the inner surface of the bearing 16 and the outer surface of the support member 3' into the left end of the bore 18 and flow back to the region of lower pressure within the central passage through the housing for which purpose a transverse bore 19 is shown in FIGS. 3 and 6 is provided which establishes communication between the bore 18 and the interior of the central passage through the housing and which is closer to the inlet 12 than to the outlet 13. The fluid medium passing through the transverse bore 19 will thereby provide a partial equalization of the axial thrust imparted to the rotor.

Each of the sealing elements 6 may be formed of two separate parts, as indicated by the dotted lines shown in FIG. 4 through the sealing element, so that between the inner ends of the two part sealing element a gap may be provided which is transversed by the central bore 18 and which is thereby filled with the fluid medium under pressure. FIG. 11 shows such a modified sealing element 6*a* which is interrupted in its middle region 20 so that this sealing element 6*a* is composed of two individual parts 6*b* between the inner ends of which the space 20 is provided. FIG. 11 illustrates also a further sealing element 21*a* which extends transverse to the sealing element 6*a*, which however may also be omitted. The function of the transverse sealing element will be described later on in detail.

If the sealing element 6a is formed of two individual parts it is advantageous to omit the transverse bore 19 mentioned above so that the two parts of the sealing element are pressed by the fluid medium under pressure in the axial bore 18 apart, whereby even if the outer ends of the sealing element will wear, a perfect seal against the surface 4 will be obtained. In such a construction it may be advantageous to close the central bore 18 on opposite ends 18*a* and 18*b* as shown in FIG. 11*a* and to fill the closed bore with a fluid medium F under pressure which will act against the inner faces of the two part sealing elements, which in turn will seal the bore in the region of the slot 5. The thus formed closed space may be provided at one end of the axial bore 18 with a valve 80 as shown in FIG. 11*b* to refill the closed space with a fluid medium under pressure when the pressure in the space is reduced due to leakage losses or to an increase of the space due to wear of the outer ends of the sealing elements. The arrangement of such a closed space is especially advanantageous if, on the one hand, it is desired to press the outer ends of two-part sealing elements against the surface 4 and if, on the other hand, a medium is conveyed which contains solid particles or the like so that the medium is not very well adapted to be fed into the bore 18 and to provide a pressure against the inner ends of the two-part sealing elements.

In a further modification as shown in FIG. 11*c* it is also possible to close one end of the central bore 18 by a movable piston 81 which for instance may be under the pressure of a compression spring 82 tending to move the piston into the bore 18. Thereby it is possible to compensate at least within certain limits any pressure loss in the interior of the aforementioned closed space and to maintain the pressure in the space substantially constant.

It is also possible to fill the space between the inner ends of a two-part sealing element with an elastic pressure member, for instance a spring 83 or a piece of elastically compressed material so that the elastic pressure element engaging the inner ends of the two-part sealing elements **66** will press the outer ends thereof against the surface **4** as shown in FIG. **11***d*. In this case the central bore which communicates with the passage **4** through the housing may be omitted. Instead of pressing the inner ends of the two-part sealing element by fluid pressure away from each other, this pressing apart of the two-part sealing elements is accomplished by the elastic members inserted between the inner ends of the two-part sealing elements which will assure that the outer ends of the two-part sealing elements will be pressed against the inner surface of the housing with the necessary force so that during rotation of the rotor again a positive to and fro movement of the two-part sealing elements relative to the housing is obtained.

FIGS. **7, 8** and **11** illustrate a modified construction in which for each cross section of the passage through the housing at least two sealing elements which cross each other are arranged, as shown by the sealing elements **21** in FIGS. **7** and **8**, respectively, by sealing elements **6***a* and **21***a* as shown in FIG. **11.** In the embodiment illustrated in FIGS. **7** and **8**, both of the sealing elements are one-piece sealing elements which have, as best shown in FIG. **8**, each an intermediate portion **22** of reduced cross section which is half of the cross section of the remaining sealing element and this reduced cross section **22** of each sealing element has an appropriate length corresponding to the relative movement of the crossing sealing elements. Each cross section of the passage is thereby sealed at four points, which increases the efficiency of the conveying apparatus especially during conveyance of fluids. In the modification as shown in FIG. **11** one of the crossing sealing elements, that is sealing element **6***a*, is formed, as described before, from two separate parts **6***b*, the inner ends of which are subjected to pressure of fluid in the central bore **18**, whereas the other sealing element **21***a* is integral and extends through the space **20** between the two part **6***b* of the sealing element **6***a*.

Such sealing element construction as shown in FIGS. **7, 8** and **11** may be used not only in the abovedescribed embodiment illustrated in FIG. **3** but also in the embodiments illustrated in FIGS. **1, 9** and **10** which will be described later on.

It is also sometimes advantageous to construct adjacent sealing elements **6**, respectively **21**, alternatingly of metal and plastic material to thereby reduce the friction between adjacent sealing elements. Adjacent sealing elements may also be formed from different metals or different materials especially if mediums are to be conveyed which cuase considerabld abrasion.

The path of the medium through the conveying apparatus is indicated for instance in FIG. **3** by the dash-dotted line *w* and the arrows P*f*. The medium passes through the passage in the housing **2** along a helical path which in the projection of FIG. **3** is shown in a zigzag line in the region of the rotor.

A conveying apparatus construction similar to that shown in FIG. **3** is illustrated in FIG. **9.** The construction shown in FIG. **9** differs from the above-described construction illustrated in FIG. **3** mainly in that the passage through the housing is constituted by two oppositely convoluted helical screw surfaces **9***a* and **9***b*, and in which medium inlets **12** are provided at the ends **10** and **11** of the two helical screw surfaces which face away from each other, whereas a single outlet **13** is provided between the adjacent ends of the aforementioned surfaces. A common rotor **3***a* is coaxially arranged in the interior of the two aforementioned helical screw surfaces **9***a* and **9***b* and the rotor is again provided with sealing elements as described before in connection with FIG. **3.** A shaft **14** integral with the rotor **3***a* projects through the bore in the right end, as viewed in FIG. **9,** of the housing **2***a* and sealing means **15** are provided in this bore which seal the shaft against the housing. The shaft **14** is connected to a motor, not shown in FIG. **9,** to rotate the rotor **3***a* relative to the stationary held housing **2***a*. Since the two portions **9***a* and **9***b* of the passage through the housing are convoluted in opposite directions, the axial forces produced on the rotor will equalize each other. However, in this construction it may also be advantageous to provide a central bore **18** and an additinal bore **118** through the rotor **3***a* which respectively communicate with the interior of the passages at different pressure regions through transverse bores **19** and **119** as shown in FIG. **9.**

A further embodiment of a converging apparatus according to the present invention is illustrated in FIGS. **1** and **2.** In this embodiment, the cylindrical support member **23,** which corresponds to the member **3'** of the rotor **3** of the embodiment shown in FIG. **3** which carries in an axial slot therethrough the sealing elements **6**, is arranged stationarily, whereas the surrounding outer housing **23***a* provided with the axial passage therethrough which is defined by a helical screw surface is surrounded by and fixed to a rotor **24** of an electromotor **25.** The rotor **24** of the electromotor is separated by an annular gap **26** from the surrounding stator **27.** The stator is provided with the usual stator winding **28** and surrounded by the motor housing **29.** In this construction there is evidently no shaft necessary for driving the cylindrical support member **23** which is actually maintained stationarily and the seal **15** for the shaft **14** shown in FIG. **3** may therefore be omitted. When the electromotor **25** is energized, the rotor **24** of the electromotor together with the housing **23***a* will be rotated relative to the stationarily held cylindrical support member **23** so that again a medium in the passage through the housing will be advanced along a helical path corresponding to the relative rotation between the member **23** with the sealing elements **6** and the housing **23***a*. The embodiment illustrated in FIG. **1** is especially advantageous due to its compact construction and the possibility of omitting the seal **15** necessary in the constructions as shown in FIGS. **3** and **9.**

In the construction shown in FIG. **1** the inlet **12***a* and the outlet **13***a* are arranged coaxially with the axis of the cylindrical support member **23.** The inlet and the outlet are provided in the covers **30** and **31** which are connected by screws **32** to the motor housing **29** and which close respectively axial openings in the housing which substantially correspond to the inner diameter of the rotor of the electromotor, so that the complete rotor may be easily assembled with and disassembled from the other components of the apparatus.

As shown in FIG. **1**, two annular spaces **34** and **35** are provided in the region of the inlet and the outlet, which spaces are traversed by the medium to be conveyed and which are connected with each other through the annular gap **26** between rotor **24** and stator **27.** As further shown in FIG. **1**, the aforementioned annular spaces **34** and **35** are connected respectively downstream of the inlet **12***a* with the latter by a transverse passage **36** and upstream of the outlet **13***a* by a corresponding transverse passage **36** so that the fluid medium may circulate through the annular spaces **34** and **35** and the annular gap **26** as indicated by the arrow Pf **2** and Pf **3**. The medium under pressure passes through the passage **36** adjacent to the outlet **13***a* and at high pressure into the annular space **35** and then through the annular gap **26** into the annular space **34** and back through the other cross passage **36** into the main passage. Due to the continuous stream of fluid medium through the annular gap **26** an advantageous cooling of the motor is obtained.

A further embodiment is illustrated in FIG. **10**. In this embodiment the cylindrical support member **43** which carries the sealing elements **6** in an axially extending slot, as described before, as well as the outer housing **42** provided with the central passage therethrough the surface of which is defined by a helical screw surface are both turnably mounted, whereby either the housing or the rotor, constituted by the member **43** with the sealing elements **6**, are connected to a drive **44**, whereas the other of the two aforementioned conponents is provided with means **45** to take up a drive therefrom. In the embodiment illustrated in FIG. **10** the rotor constituted by the cylindrical support member **43** and the sealing elements **6** are driven from a motor **44** by means of a shaft **44***a*, whereas the housing **32** carries a coupling disk **45** provided for instance with two coupling pins **46** so that the housing may be connected to a member to be driven. Evidently it is also possible to reverse the arrangement and to connect the housing **42** to the motor **44** and to provide a coupling on the member **43**. In the arrangement illustrated in FIG. **10**, when the rotor is driven by the motor **44**, the liquid in the interior of the housing **42** will necessarily cause a rotation of the housing so that the embodiment illustrated in FIG. **10** will act as hydraulic coupling. In order to prevent overloading of the motor it is advantageous to provide in the housing **42** at least one passage **48** communicating with the central passage through the housing, but normally closed by an overpressure valve **47** arranged in the region where the highest pressure will occur during operation and which is moved to its open position, as shown in FIG. **10**, when the turning moment imparted to the motor through the coupling reaches a predetermined maximum value so that the fluid medium may circulate as indicated by the arrows P*f* **4** from the region of high pressure in the central passage through the passage **98** to the region of low pressure, whereby the housing is not rotated any longer and the coupling disk **45** will remain at standstill.

The manufacture of the helical screw surface defining the central passage through the housing as illustrated in the embodiments of FIGS. **1–11** is connected with considerable difficulties, especially if a smooth running surface for the sealing elements **6**, **6***a* or **21** should be obtained. This is especially the case when the central passage through the housing defined by the aforementioned helical screw surface is to be formed from abrasion resistant or other material which has special chemical and/or mechanical characteristics. Increased difficulties are encountered when the passage through the housing is an annular passage having inner and outer surfaces in the form of helical screw surfaces, as will be described later on. In addition, it is sometimes desirable that the part of the housing which is in contact with the medium to be conveyed, that is the part of the housing which defines the helical screw surface **4**, is formed from a different material than the remainder of the housing. According to a further development of the present invention, it is therefore suggested that the helical screw surface which defines the passage of the housing is formed by a thin walled tube or a screw bushing, as shown at **54** in the embodiment illustrated in FIG. **14**.

FIGS. **12** and **13** schematically illustrate the manner in which such a screw bushing **54** may be formed from a tube **55**. The apparatus **56** illustrated in FIGS. **12** and **13** comprises a form having a central portion **57** formed with a central passage therethrough having an inner surface corresponding to the outer surface of the screw bushing **54** to be produced. The member **57** is preferably a two-part member **57***a* and **57***b*, as clearly shown in FIG. **13**, and a pair of covers **59** and **60** abut against the end faces of the central member **57** and are pressed thereagainst by bolts and nuts as clearly illustrated in FIG. **12**. The cover **59** is provided with a central bore **61** through which a fluid under high pressure may be pressed in the interior of the tube **55**. The ends of the tube are sealingly engaged by the inner surfaces of the aforementioned covers or at least one or a plurality of ventilating passages **78** are provided to permit air surrounding the outer surface of the tube **55** to escape to the exterior of the form. The tube **55**, which is shown in FIGS. **12** and **13** in undeformed condition, is deformed under the influence of the pressure medium **62** passed into the interior of the tube to the configuration as indicated in dotted lines in FIG. **12**. In this manner, an exact configurated screw bushing **54** with excellent surface quality at its inner face **4** may be obtained. In addition, it is possible to make the screw bushing **54** relatively thin walled and from different materials especially adapted for the medium to be conveyed by the apparatus. Due to the thin wall of the screw bushing a relatively expensive material for forming the same may be used without unduly increasing the price thereof. Another possibility to form the screw bushing is to form the same from hard metal alloys for inseance from sintered or preferably cast hard metal alloys. Such screw bushings may for instance be cast according to the lost wax method with sufficient precision and they will have a very high resistance against abrasion, which is especially advantageous during conveying of cement paste, whereby the cost of such a screw bushing inserted for instance in an outer housing **102**, as shown in FIG. **14**, is relatively small.

As clearly shown in FIGS. **14** and **16**, the outer surface of the screw bushing **54** is surrounded by a helical passage **72** which is encompassed by a corresponding portion of the housing **102** of the conveying apparatus illustrated in FIG. **14**. The helical passage **72** is adapted to receive or to be flown through by a fluid medium which will impart an outer pressure and/or to serve to cool, respectively to heat the screw bushing **54**. For this purpose an inlet and outlet **73** and **74** are provided in the outer housing **102** which surrounds the screw bushing. If a counter pressure in radially inward direction onto the screw bushing **54** is desired, then a fluid medium under high pressure is passed through the passage **73** into the helical space **72** while the passage **74** is preferably closed, and if heat should be transmitted to or conveyed from the screw bushing, then a heating or cooling medium is circulated through the helical passage **72** and this medium may also be maintained at high pressure if the aforementioned radially inward counter pressure should be desired. As clearly shown in FIGS. **14** and **15**, the outer housing **102** is provided with an axial bore **110** the diameter of which is so dimensioned that the screw bushing **54** will engage and thereby be supported along a helical line in the bore **110** of the housing.

THe screw bushing is preferably provided at its left end, as viewed in FIG. **14**, and as also shown in the partial view of FIG. **18** with a radially extending attaching flange **111**.

This flange **111** is in axial direction slightly yeildable so as to compensate for different axial expansions of the screw bushing and the surrounding housing **102** which will especially occur when the screw housing and the outer housing have different temperatures. Such flange **111** may be provided on opposite ends of the screw bushing **54** but, advantageously, and as shown in FIG. **14**, only one end of the screw bushing is provided with a flange **111** whereas the other end, shown in FIG. **14** as the right end, is cylindrically formed so as to be movable in axial direction along a sealing ring **112** located in an annular groove of the outer housing **102** and surrounding in a sealed manner the cylindrical end of the screw bushing.

A further embodiment according to the present invention is illustrated in longitudinal and transverse cross-sections in FIGS. **16** and **17**. In this embodiment the conveying space for the medium to be conveyed by the apparatus is in the form of an annular space having inner and outer surfaces, formed by a pair of coaxial screw bushings **154** and **254**. A likewise annular support member or support means **103** which carries the sealing elements **6** is coaxially and rotatably arranged within the thus formed annular space **120**. The support means **103** has a cross section in form of a hollow cylinder and is provided in the region **6** with axial extending transverse slots **5** in which the sealing elements **106** are guided in the manner as described before. As evident from FIGS. **16** and **17**, the sealing elements are positively moved in direction transverse to the axis of the support means due to the configuration of the screw bushings **154** and **254**. The annular support means **103** is provided at the sides thereof facing the suction side of the conveying apparatus **101** with an endwall **121** from which a drive shaft **122** extends in axial direction for turning the support means **103** about its axis. The endwall **121** is provided with a plurality of passages **124** for passage of the medium to be conveyed therethrough. The medium to be conveyed enters the apparatus through the inlet **121**, and as indicated by the arrows *Pf* **60** and *Pf* **61**, the medium to be conveyed may pass in the region radially outwardly of the support means **103** as well as through the passages **124** into the region **126** which is located radially inwardly of the support means. The medium passes therefore in two streams through the apparatus whereby one stream, that is the inner stream in the region **126** is adjacent the screw bushing **254** and the other outer stream in the region **127** is adjacent the outer screw bushing **154**, as clearly shown in FIGS. **16** and **17**.

The support means **103** may be mounted only at one end thereof, for instance at the end shown as the left end in FIG. **16**, by means of the shaft **122** in the region of the suction side of the conveying apparatus **101**. Preferably, however, the support means **103** is mounted in an additional bearing on the pressure outlet side of the apparatus in the neighborhood of the outlet **130**. For this purpose an annular bearing **301** is provided which is fastened to the housing **102** and which is formed with an annular groove **302** in which the right end of the support means **103** is turnably mounted. This will assure proper mounting and sealing of the support medium means **103**. The common outlet **130** is provided at the pressure end of the conveying apparatus **101** and the pressure medium passes through an annular space **131** into the outlet **130**. The apparatus preferably includes further a cylindrical member **132** projecting in axial direction from the cover which closes the housing **102** at the right end, as viewed in FIG. **16**, and which carries the screw bushing **254**.

As shown in FIGS. **14** and **15**, each of the sealing elements **6** may be formed of two parts of equal length as evident from the parting line **206** in FIGS. **14** and **15**. The parting line **206** is located in the region of the bore **18** which is filled with a fluid under pressure. This further development according to the present invention will assure the positive movement of the sealing elements in transverse direction since the combined length of the two parts **6*a*** and **6*b*** of each sealing element **6** is the same as that of the one-part sealing element; however, the fluid medium under pressure may pass through the slit **206** between the inner ends of the two parts **6*a*** and **6*b*** of each sealing element to thereby press the outer ends against the inner surface of the screw bushing **54**. It is also possible to vary the pressure acting against the inner ends of the sealing elements over the axial length of the apparatus. Thus, the bore **18** does not necessarily extend over the whole axial length of the screw bushing and be closed at one end as shown in FIG. **14**, but the central bore **18** may also communicate through a cross bore **19** with the space of higher pressure, as for instance shown in FIG. **3**. It is also possible to arrange two or more such bores through the support means which are separated from each other. This is shown in FIG. **9** for the separate bores **18** with the outlet **19**, and **118** with the outlet **119**. The medium to be conveyed can pass with the pressure prevailing in the region of the outlet **13** through the bores **18** to the bore outlets **19** which are located in the region of an intermediate pressure, and the sealing elements **6** which are located between these bores **19** and the outlet **13** will therefore, in the region of their gaps **206**, be impinged with relative high pressure. It is understood that the sealing elements **6** shown in FIG. **9** are made in this arrangement also as two part sealing elements **6*a*** and **6*b*** as described in connection with FIG. **14**. Such an impingement of the sealing elements with high pressure fluid would cause in the region of the inlets **12** unnecessarily high friction between bushing and sealing elements and wear at the outer ends of the latter. Therefore, a second bore **118** is provided which has its inlet **119** in the region of medium pressure and its outlet at the region of the low pressure so that the sealing elements between the transverse bores **119** and the inlets **12** of the apparatus are impinged at the inner ends thereof with a lower pressure.

FIG. **19** illustrates a further advantageous modification of the apparatus according to the present invention. As shown in FIG. **19**, the sealing elements **6** are divided in three separate groups **306**, **307** and **308**. In each group the sealing elements are arranged closely adjacent to each other so that side faces of the sealing elements engage each other and they are guided for movement in direction transverse to the axis of the apparatus in axially extending transverse slots **5** through the cylindrical support means **3.** For a simplification of manufacture these slots **5** may be constructed as a single, axially extending slot which is divided into separate portions by inserts *7a* and *7b* which are held in the slots by transverse screws or the like as illustrated for instance in FIG. **5.** The essential advantage of dividing the sealing elements in individual groups **306, 307** and **308** resides in the fact that the pressure of the medium to be conveyed and acting on a sealing element **6** is not transmitted in axial direction through all sealing elements. Thus, for instance, if in the region of the left end, as viewed in FIG. **19** of the apparatus, assuming that the medium outlet not shown in FIG. **19** is at the left end of the apparatus, there should be medium pressure P 21 of 21 atm., such pressure will be transmitted in axial direction on the left-most sealing elements **6** of the group of sealing elements **306** and be transmitted through all the sealing elements of this group. This pressure will, however, not be transmitted to the sealing elements of the other two groups since the right-most sealing element of the group **306** abuts at **309** against the insert *7a.* In the region of the second group **307** of the sealing elements may for instance be a pressure P 14 of 14 atm. and the pressure on the sealing elements of the group **308** of sealing elements may for instance be between 0–7 atm. as indicated at **P 7.** The sealing elements of the group **307** are therefore subjected to axial pressures between 14 and 7 atm. and the sealing elements of the group **308** will be subjected to a pressure between 7 and 0 atm. The individual sealing elements will therefore be subjected only to partial pressures of the total pressure acting in axial direction so that they are subjected to less friction and less wear. It is mentioned at this occasion that the relative movement of adjacent sealing elements is usually relatively small which will reduce the wear on the side faces of the sealing elements.

The features of dividing the sealing elements in individual groups as shown in FIG. **19** for the groups **306, 307** and **308** can evidently also be used in the other embodiments as described before, for instance in the embodiment as illustrated in FIGS. **16** and **17.**

It is also possible to combine the feature of dividing the sealing elements into individual spaced groups as shown in FIG. **9** with the feature of providing a plurality of separate axial fluid passages through the cylindrical support member, as shown in FIG. **9,** so as to further reduce the axial pressure on the sealing elements.

In the embodiment as shown in FIGS. **16** and **17,** in which a greater number of sealing elements are provided than for instance in the embodiments shown in FIGS. **1** and **2,** a higher pumping pressure may be obtained for the same axial length of the apparatus.

The conveying apparatus according to the present invention has the advantage that the apparatus can be operated with a high as well as a low rotational speed depending on the medium to be conveyed. Especially for mediums of low viscosity it is possible, depending on the axial length of the apparatus, to obtain relatively very high pumping pressures. This is especially the case if a great number of sealing elements **106** is provided as for instance shown in the embodiment of FIGS. **16** and **17.** This embodiment is especially advantageous if relatively great amounts of mediums have to be conveyed. On the other hand, it is also possible with the apparatus according to the present invention, especially with the embodiment shown in FIG. **14,** to convey mediums of very high viscosity, for instance cement paste. Thereby it is advantageous if the elements which are subjected to greatest wear may be easily exchanged without disassembling the whole apparatus and in which for instance the passage for the medium through the housing is formed by a separate screw bushing or bushings.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of conveying apparatus differing from the types described above.

While the invention has been illustrated and described as embodied in conveying apparatus, especially a pump having an elongated housing formed with an axial passage therethrough defined by a helical screw surface, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. In an apparatus of the character described, a combination comprising elongated housing means having an axis being formed with an axial passage therethrough defined by a helical screw surface; substantially cylindrical support means extending in the direction of said axis through said passage and having a cross section smaller than that of the passage, said support means being arranged in said passage so as to engage said surface substantially tangentially along a helical line; and a plurality of sealing elements mounted on said support means and extending diagonally through said passage and engaging said surface, said plurality of sealing elements being arranged closely adjacent to each other in the direction of said axis and being movable relative to each other in a direction transverse to said axis, each of said sealing elements having a width in the direction of said axis which is considerably smaller than the pitch of said screw surface.

2. A combination as defined in claim **1,** wherein said elongated housing means is closed at one and open at the other end thereof and including a bearing for said cylindrical support means at the closed end of said housing means, a drive shaft extending through the other end of said housing means and being connected to said cylindrical support means, and sealing means around said drive shaft in said other end of said housing means.

3. A combination as defined in claim **1,** wherein adjacent sealing elements are alternately formed from different material.

4. A combination as defined in claim **3,** wherein adjacent sealing elements are alternatingly formed from metal and plastic, respectively.

5. A combination as defined in claim 1, wherein said support means is provided with at least one axially extending slot therethrough, said sealing elements extending through and being guided in said slot for movement in said transverse direction.

6. A combination as defined in claim 5, wherein each of said sealing elements comprises two parts having inner ends located in said slots spaced from each other and resilient means sandwiched between said inner ends of said two parts for biasing the latter away from each other.

7. A combination as defined in claim 5, wherein said support means is provided with two axially extending slots therethrough arranged at an angle with respect to each other, said sealing elements being arranged in said two slots so that adjacent sealing elements in one slot cross corresponding sealing elements in the other slot, each of said sealing elements having in the region where it crosses the other sealing element a portion of reduced thickness so that the combined thickness of the crossing portion is equal to the thickness of the remainder of each sealing element, the length of the portion of reduced thickness corresponding to the relative movement of the crossing sealing elements.

8. A combination as defined in claim 5, wherein said support means is provided with at least two axially extending slots arranged at an angle with respect to each other, said sealing elements being arranged in said slots so that adjacent sealing elements in one slot cross corresponding sealing elements in the other slot, at least one of each of the crossing sealing elements being made from two parts having inner ends spaced from the corresponding crossing sealing element, and means for biasing said inner ends away from each other.

9. A combination as defined in claim 5, wherein said sealing elements have parallel side faces and are arranged in said slots so that the parallel side faces of adjacent sealing elements engage each other.

10. A combination as defined in claim 5, and including insert means in said slot fixed to said support means and dividing said slot into at least two axially spaced sections.

11. A combination as defined in claim 10, wherein said sealing elements adjacent said insert means abut against the latter.

12. A combination as defined in claim 5, wherein said passage surface is defined by two oppositely convoluted screw surfaces aligned along a common axis and spaced in axial direction from each other, and including a pair of fluid inlet means respectively arranged at the ends of said screw surfaces which face away from each other and a common fluid outlet means communicating with said passage at the space between the facing ends of the two screw surfaces.

13. A combination as defined in claim 5, and including fluid inlet means communicating with one end of said passage, fluide outlet means communicating with said passage axially spaced from said inlet means, and means for rotating said housing means and said support means with said sealing elements relative to each other so that material entering through said inlet means will be discharged at higher pressure at said outlet means.

14. A combination as defined in claim 13, wherein said support means is formed with an axial bore therethrough having a diameter greater than the thickness of said sealing elements and communicating with said passage in the region of said outlet means.

15. A combination as defined in claim 14, wherein said axial bore communicates with said passage in the region of said inlet means.

16. A combination as defined in claim 5, wherein said cylindrical support means is formed with an axial bore having a diameter greater than the thickness of said sealing elements, each of said sealing elements being formed of two parts having inner ends in said bore, and including a fluid medium under pressure in said bore acting on said inner ends of the two-part sealing elements for pressing the outer ends against said surface.

17. A combination as defined in claim 16, wherein said bore is closed at opposite ends.

18. A combination as defined in claim 17, and including means communicating with said bore for filling the latter with a fluid medium under pressure.

19. A combination as defined in claim 17, wherein one end of said bore is closed by a piston tightly guided therein and resilient means engaging said piston for pressing the latter against the other closed end of said bore for pressurizing the fluid in said bore.

20. A combination as defined in claim 1, and including means for stationarily mounting said support means and means for rotating said housing means about its axis relative to said stationary support means.

21. A combination as defined in claim 20, and including inlet and outlet means for the medium to be conveyed, said inlet and outlet means communicating with the interior of said housing means and being arranged substantially coaxial with said cylindrical support means.

22. A combination as defined in claim 21, and including wall means enclosing a pair of annular spaces about said inlet and outlet means, said pair of annular spaces communicating with each other through said annular gap, and passage means respectively providing communication between said inlet means and one of said annular spaces and between said outlet means and the other of said annular spaces so that said medium will circulate through said spaces and said gap.

23. A combination as defined in claim 1, and including a support for rotatably mounting said housing means and said support means with said sealing elements and including drive means for rotating one of the aforementioned two means and means for taking up a drive from the other of said two means.

24. A combination as defined in claim 23, wherein said drive means is connected to said support means for rotating the latter and the sealing elements carried thereby relative to said housing means, and said means for taking up a drive comprising a coupling disk fixed to said housing means for rotation therewith.

25. A combination as defined in claim 23, and including passage means connecting one end of said axial passage through said housing means with the other end thereof.

26. A combination as defined in claim 25 and including adjustable relief valve means in said passage means.

27. A combination as defined in claim 1, wherein said housing means comprises outer annular wall means and a bushing located within said outer annular wall means, said passage with said helical screw surface being formed by said bushing.

28. A combination as defined in claim 27, wherein said bushing is formed from hard metal.

29. A combination as defined in claim 27, wherein said bushing is provided at least at one end thereof with a connecting flange which is slightly yieldable in axial direction.

30. A combination as defined in claim 27, wherein said bushing has a thin wall of substantially uniform thickness and being provided at the outer periphery thereof with a surface corresponding to the inner surface thereof to form between the inner surface of the outer wall means and the outer surface of said bushing a passage adapted to receive fluid for providing pressure on the outer surface of said bushing, respectively for cooling or heating the latter.

31. A combination as defined in claim 30 wherein said annular wall means has an inner cylindrical surface and wherein the outer surface of said bushing engages said inner cylindrical surface along a helical line.

32. A combination as defined in claim 1, wherein said passage through said housing means comprises an annular passage the inner and outer surfaces thereof being defined by helical screw surfaces, said support means comprising an annular cylindrical member coaxially arranged in said passage.

33. A combination as defined in claim 32, wherein said housing means comprises two coaxial bushings on which said inner and outer surfaces are provided and wall means supporting said bushings.

34. A combination as defined in claim 32, wherein said annular cylindrical member is provided with at least one axially extending slot therethrough, said sealing elements extending through and being guided in said slot for movement in said transverse direction.

35. A combination as defined in claim 32, wherein said annular cylindrical member is provided with a plurality of axially extending slots therethrough which are angularly displaced from each other and a plurality of axially adjacent sealing elements extending through each of said slots and being guided therein for movement in said transverse direction.

36. A combination as defined in claim 32, wherein said housing means has a pair of end walls one of which is provided with inlet means and including a connecting channel at the end of said passage adjacent to the other end wall and communicating with outlet means provided in said other end wall.

37. A combination as defined in claim 32, wherein said annular cylindrical member has at one end thereof a transverse endwall formed with openings therethrough for the passage of the medium to be conveyed into an inner region of said axial passage through said housing means.

38. A combination as defined in claim 37, and including shaft means projecting outwardly from said end wall for rotatably supporting and driving said support means.

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