



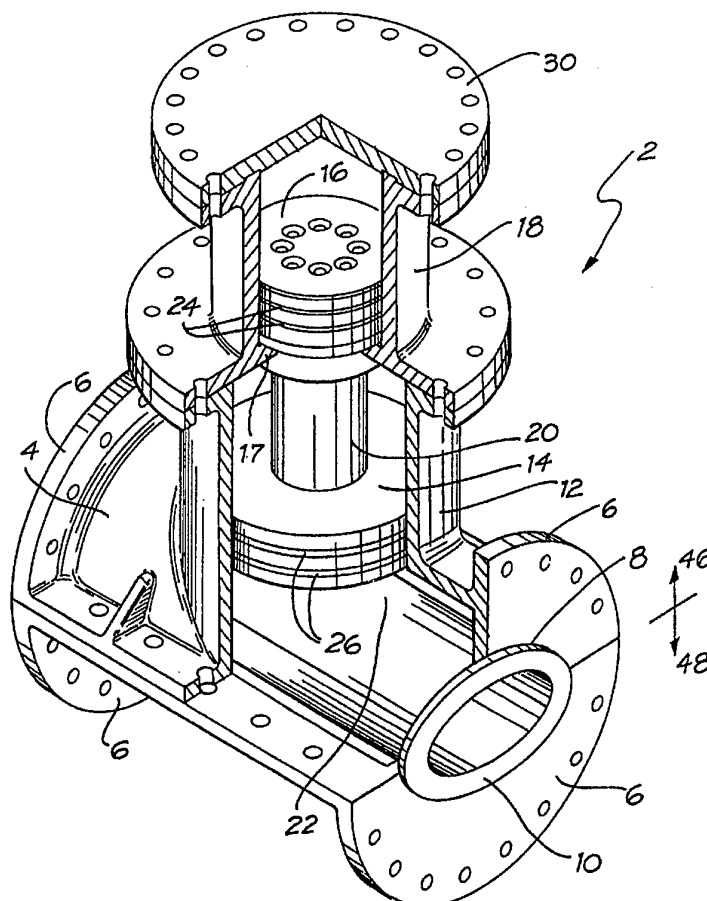
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(54) Title: A FLOWABLE MATERIAL HANDLING DEVICE

(57) Abstract

A deformable membrane (10) for a flowable material handling device (2) having an internal chamber or passage for the flowable material, the membrane (10) being adapted to be compressed or deformed thereby altering the volume of the internal chamber wherein the chamber cross section in the uncompressed state comprises a major axis and a minor axis and the chamber being adapted for deformation to take place parallel to the minor axis. Additionally, deforming means for deforming the membrane (10) to produce a pre-determined volume change to the internal chamber of the membrane (10) and an actuation means for positively moving the sides of the membrane (10) to thereby compress and decompress the membrane (10), are also disclosed.



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A FLOWABLE MATERIAL HANDLING DEVICE

FIELD OF INVENTION

The present invention relates to membranes for flowable material handling devices and flowable material handling devices which can include peristaltic pumps, valves and mixing devices. More particularly, the flowable material handling device can be used in industrial and mining applications to handle such materials as coal and ash slurries and other mining slurries, as well as food slurries and live slurries, pastes and other heavy viscosity substances.

BACKGROUND ART

10 The pumping of slurries from locations such as mining pits to power house stations is generally performed by rotational pumps, piston pumps or diaphragm pumps.

Rotational or centrifugal pumps suffer from the disadvantage of not being able to provide a straight flow path for the fluid being pumped and are limited by the maximum size of particle which is permitted to be passed through the pump. Piston pumps of the Schwing type require the use of shear valves in conjunction therewith and are also limited by the size of particle which is permitted to pass through the pump. Diaphragm pumps suffer the same difficulties as the rotational and piston pumps. These pumps suffer from an inability to be located in series with like pumps or with different sorts of pumps, generally because they do not offer a straight through flow path without the use of by passes and valves.

20 Peristaltic pumps are known in many fields, but to date this type of pump has been restricted in use to areas which relate to the pumping of liquids usually in small quantities, such as for pumping blood in operating theatres. Attempts to increase the size of peristaltic pumps to handle larger quantities and more aggressive materials such as slurries have not gained acceptance because of restricted service life, operating pressures, capacity and other related characteristics of such pumps. The service life of the flexible tubes or linings of such pumps are greatly reduced due to the repeated flexing cycles.

The peristaltic action of prior art pumps is generally produced by the mechanical action of the compression of a single tube in a linear sequence to produce movement of a fluid or flowable material through the membrane of the pump.

30 The use of peristaltic type devices for use with food and live slurries bearing water borne creatures such as fish and shrimp, is greatly restricted because of the damage to the food or the animals contained in the slurry. Furthermore, those shown in, for example, GB-A 2,179,404 cannot cope with bulky objects such as coal because they are closed in their rest state, and opening or expanding provide the pumping action.

SUMMARY OF THE INVENTION

The present invention provides a membrane for a flowable material handling device, said membrane comprising at least one flow chamber which is adapted to be deformed or compressed to thereby reduce the volume of said chamber; characterised in that said
5 chamber when in an uncompressed state has a cross section which comprises a major and a minor axis, the chamber being deformed or compressed in a direction perpendicular to the major axis or parallel to the minor axis.

The present invention also provides a membrane having inner and outer surfaces, said inner surfaces defining a fluid passage whilst said outer surface is adapted to engage a
10 compression means to collapse said fluid passage, characterised in that said fluid passage when uncompressed has, in cross section, a first axis in the direction of which compression occurs, and a second axis crossing said first axis, wherein said second axis is longer than said first axis.

Advantageously the invention also provides that the membrane has a flange at each end
15 enabling the membrane to be secured into a housing.

It is further advantageous to provide that the flanges at each end include means allowing adjacent membranes to seal or be held stationary with respect to each other.

Preferably the invention also provides that the flanges of the membranes can also include a means to mate with a complementary means on a housing to hold the flange in place
20 relative to the housing.

It is further preferable that the membrane is manufactured from Kevlar or neoprene or polyurethane or natural rubber or a composite material.

It is also further preferable that the cross section of the membrane, in uncompressed state, is substantially elliptical, or substantially diamond, or substantially teardrop or partially
25 circular, or partially elliptical.

It is further preferable that the membrane is part of a flowable material handling device which can be a pump or a valve or a mixing apparatus, or a single apparatus which can serve any one of these purposes depending upon the sequence of energisation of the membranes.

30 A membrane having the above inventive features can provide an improved degree of flexing of the membrane lining. That is, the angle through which adjacent portions move through when the membrane is being collapsed or compressed, is minimised. This leads to a lower energy consumption to activate the membrane when compared with membrane linings not embodying this feature.

The inventive lining which may be installed in a pump, mixing device or valve will result in extended life when compared to a circular lining, whilst at the same time requiring less pressure and permitting relatively higher displacement than conventional slurry pumps or peristaltic pumps.

- 5 The present invention further provides a flowable material handling assembly, comprising an element having a collapsible membrane section which defines a passage through said element wherein the pressure applied to deform the membrane produces a predetermined volume change.

10 Preferably the invention provides for the transferral of a set amount of fluid into a chamber to deform a membrane lining. It is also preferable that the fluid producing the pressure around the membrane is in a closed system (that is a system which is not added to) and is forced into the chamber by means of a piston actuation means having a finite length of travel.

15 It is also advantageously preferable that the pressure applied to deform the membrane is applied by means of an incompressible fluid.

It is also preferable that the incompressible fluid is pressurised by a piston means, which piston means travels a pre-determined distance and the maximum travel of said piston means provides a pressure which is bearable by said membrane.

20 It is also advantageously preferable that the piston means is moved by a piston actuation means.

A further preferable feature is that hydraulic pressure is applied to provide movement to the piston means.

Advantageously the actuation piston means can be either a pneumatic or hydraulic powered ram, mechanical means or electromagnetic means.

- 25 It is also preferable when the piston actuation means is a hydraulic means, a control valve is provided to direct fluid to a low pressure side of a hydraulic actuator thereby causing the piston actuation means and or the piston means to move to a starting position, whereby the membrane is brought back to an uncompressed state.

30 Advantageously there is also preferably provided that the membrane is of a shape having a major and minor axis in cross section when in an uncompressed state, such as for example the membrane is substantially elliptical or substantially diamond or substantially teardrop or partially elliptical or partly circular in shape.

It is also preferable that the assembly is a pump or a valve or a mixing apparatus, or able to achieve any one of these functions depending upon the sequencing to compress the membranes.

These features produce the advantage of preventing the membrane from rupturing. In this way the maximum pressure applicable to the membrane is also limited.

The invention further provides a peristaltic pumping assembly comprising at least one membrane having at least one actuation means connected thereto said actuation means being forced together to thereby compress the membrane and positively move apart the membrane to thereby decompress the membrane.

The invention also further provides a flowable material handling device including at least one substantially tubular shaped membrane having connected thereto at least one actuation means, the actuation means having two components located at diametrically opposite portions of the membrane, the two components of the actuation means being adapted to move towards and away from each other thereby selectively compressing and decompressing the membrane.

It is preferable that when more than one membrane is used one set of actuation means is utilised per membrane, so that membranes and actuation means are positioned adjacent like membranes and actuation means to thereby form a flowable material handling device.

It is preferable that when one membrane is used, more than one actuation means is utilised on the membrane, to form a flowable material handling device.

It is further preferable that the actuation means is comprised of a set of actuation means.

It is also further preferable that a set of actuation means is made up of opposing actuation means configured to compress and decompress the membrane required.

It is advantageously preferred that the actuation means is a single actuation means which cooperates with a stationary surface so configured as to compress and decompress the membrane when required.

Preferably the actuation means are bonded plate actuators activated by electromagnetic coil, or mechanical oscillatory drive, or hydraulic, air or pneumatic cylinder or other direct mechanical link. Irrespective of the drive used the actuation means provides the decompression force for the membrane and bonded plate actuators, as well as the compression force.

When the membranes or membrane are compressed and decompressed in a sequential fashion the membrane or membranes can act as a pumping member to move such materials as food or other slurries through the membrane.

An advantage of the present invention is that the membrane can pump, whether total or partial closure of the membrane occurs. In this way such things as critical particles or living species (such as fish) in the liquid medium can be maintained in optimum or living form rather than crushed by the membrane. Preferably the membranes utilised in the above
5 are of the type that have a major and a minor axis of the opening through the membrane, when in an uncompressed state, as such a membrane will have a built in axis of least resistance to compression as well as the advantage of providing a lower distance of travel of the sides of the membrane to effect compression thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

10 The embodiments of the present invention will now be described, by way of example only, with respect to the drawings in which:

figure 1 is a part sectional, perspective view of an element embodying the present invention;

15 figure 2 is a perspective view of a membrane lining as might be used in the apparatus of figure 1;

figure 3 is an exploded view of the apparatus of figure 1;

figure 4 is a sectional side elevation of a preferred feature;

figure 5 is a perspective view of single peristaltic pump having multiple elements of the apparatus of figure 1;

20 figure 6 is a plan view of a tandem peristaltic pump embodying twelve (12) elements;

figure 7 is a side elevation of the apparatus of figure 6;

figure 8 is a front elevation of the apparatus of figure 6;

figure 9 is a cross section through the apparatus of figure 2;

25 figure 10 is a schematic view of a pump and membrane flange detail;

figure 11 is the sequence of deformation of the membrane linings to produce a peristaltic pumping action;

figure 12 is the apparatus of figure 11 showing the sequence used to effect a mixing action by deformation of the membrane linings;

30 figure 13 is two membrane cross sections, one part of the prior art, the other not;

figures 14 to 16 are a cross section of alternative shapes to that figure 2;

figure 17 is a diagrammatic side elevation of an apparatus of a further embodiment;

figure 18 is a diagrammatic front elevation of the apparatus of figure 17;

figure 19 is a diagrammatic plan view the apparatus of figure 17;

figure 20 is diagrammatic part plan view the apparatus of figure 18;

5 figure 21 is in diagrammatic fashion a mechanical means for the compression and decompression of the plate actuators;

figure 22 is diagrammatic view of an alternative apparatus to figure 21; and

figure 23 is diagrammatic view of further arrangement.

DETAILED DESCRIPTION OF DRAWINGS

10 In figure 1 is an element 2 which can be used as part of a peristaltic pump, a valve or mixing apparatus. Element 2 comprises a body 4 having mounting plates 6 at either end. The mounting plates 6 have shaped apertures 8 to receive a similarly shaped membrane 10 as illustrated in figure 2. Attached to the body 4 is a cylinder 12 in which moves a piston 14. The piston 14 is linked to an actuating piston 16 inside an actuating cylinder 18 by means of link rod or shaft 20. When the piston 14 is in the fully retracted position in the
15 cylinder 12 and the volume 22 (which is located between membrane 10 and the inside diameter of the body 4), are filled with a finite amount of incompressible fluid such as hydraulic fluid.

20 Thus when actuating cylinder 18 and actuating piston 16 is actuated, thereby pushing piston 14 from its retracted position to the limit of its travel the fluid in cylinder 14 and volume 22 will compress the central portion 58 of membrane 10 so that it is substantially fully closed. The piston 16 is prevented from any further travel by means of stop 17.

25 Figure 3 is an exploded view of the element 2 of figure 1. The features illustrated in figure 1 are identified with like reference numbers. The actuating piston 16 and piston 14 each have seals or rings 24 and 26 respectively, to assist the sealing of the pistons to the cylinder walls of the respective cylinders 18 and 12. A link rod gland 28 seals the internal chambers of cylinders 18 and 12, to prevent communicable passage of air or hydraulic fluid between the cylinders 18 and 12. A cover 30 seals off the top of cylinder 18.

30 Figure 1 helps to illustrate the fixed or discreet volume and displacement feature of the present invention. The cylinder 12 and volume 22 which is located between the body 4 and the membrane 10 are of finite volume. This is combined with the length of travel of the piston 14 which is also of limited travel because actuating piston 16 has its travel also limited by stop 17. The cylinder 12 and actuating cylinder 18 and associated actuating piston 16 dictate the maximum stroke of piston 14. Once the piston 14 has travelled its maximum distance it can travel no further, and thus there is no risk over pressurising the

membrane 10. In prior art systems, an over pressuring situation can occur resulting in a risk of ballooning and thus fracturing of a weak point of the membrane. When actuating piston 16 is forced upwards or away from the membrane 10, the piston 14 is drawn back with it. As piston 14 is drawn back, a negative pressure is produced around the membrane 10, thus
5 providing a suction force inside the membrane 10.

Illustrated in figure 4 is a detailed view in cross section of the piston 14 and actuating piston 16. It will be noted in this figure 4 that a valve block 32 provides a connection via a communicable passage 34 to the low pressure side 36 of the actuating piston 16. Once maximum travel of piston 14 has been achieved (by virtue of piston 16 engaging stop 17)
10 the valve block 32 will prevent further pressure being applied to the cylinder 18 and thus to actuating piston 16 and divert operating pressure through the passage 34 to force the piston 16 back into its retracted position. This will draw the piston 14 to its fully retracted position and thus restoring the membrane 10 to its undeformed state. In figure 4, the link rod gland 28 is integrally formed in the base of cylinder 18, which is also the top of
15 cylinder 12.

Because the fluid acting on the membrane 10 is in a closed system, retraction of piston 14, by actuating piston 16 will produce a reduced pressure effect, to draw the membrane 10 back to its uncompressed state. This will produce a suction in the pump or fluid chamber.

In figure 5 is a pump assembly 38, made of six assembled elements 2 mounted together in series. They are located in line and sealingly secured to each other by bolts through flanges
20 40 of pump body 4. The flanges 40 are comprised of the muted mounting plates 6 of figure 1. The left hand side 42 is the inlet to the pump 38 whilst on the right hand side 44 is the outlet.

The use of identical elements 2 provides several maintenance advantages. If an actuator cylinder 18 fails, the malfunctioning of one particular element will not prevent the
25 operation of the pump assembly 38. The pump assembly 38 will still operate but the sequencing can be reprogrammed to use those serviceable elements 2 remaining to pump the same volume. This may require the speed of actuation to be increased. When routine shut down occurs the problem can be fixed or, providing the membrane 10 does not require
30 removal, a fitter can repair the failed actuator cylinder whilst the pump assembly is operating. Should a membrane require removal, the pump element 2 can be replaced by a section of substantially incompressible pipe to allow pumping to continue whilst repairs are being made.

Another advantage resulting from the connection of elements in series to form a pump
35 assembly 38 is that a standby element 2 can be kept on hand to be brought into service when required. If a quick release clamping system is used (such as described later),

interchange of elements 2 can take place relatively quickly. The series connection does not require the adjacent assembly of elements 2. A series connection can utilise a substantially incompressible pipe member employed to connect or join each pump element.

By providing a split body on element 2, which has an upper half 46 and lower half 48 (as illustrated in figure 1 and 3), however if 48 which is the opposite actuator cylinder 18, can be separated from the upper half 46, so that the membrane 10 can be quickly removed and replaced. When the upper half 46 and lower half 48 and adjacent elements 2 are held together by a quick release clamp, quick maintenance turn around times can result. Such a clamp will be described in more detail later.

10 The elements 2 can be mounted either so that the longitudinal axis through the piston 14 is on the vertical or through any direction which is convenient. The preferred configuration is horizontally opposed.

In figures 6 to 8 is a horizontally opposed peristaltic pump assembly 54 similar to the apparatus of figure 5. The elements 50 and 52 are oriented so that their longitudinal axis is on the horizontal. In this way a single double acting actuating cylinder 18 can be used to operate each of the pump elements 50 and 52. In figure 6, each of the elements 50 are in fact shown with their membranes in the fully compressed state whilst in elements 52 they are illustrated in a fully uncompressed state.

Elements 2, 50 and 52 can be constructed and operated so that energy is consumed only when the membrane is compressed or deformed. Preferably however, energy is expended to retract the actuating piston 16, thereby producing a reduced pressure around the membrane 10 in order to produce suction inside the membrane 10.

As will be seen from figure 2 and 9 the pumping membrane 10 has a central portion 58 and mounting flanges 60 and 62. Figure 9 is a cross-section through line IX to IX of figure 2. A communicable or fluid passage 64 passes through the membrane 10 and has a cross section when uncompressed as illustrated in figure 9. In the uncompressed state there is a minor axis 66 and major axis 68. The mounting plates 6 (as illustrated in figure 1) form flanges 40 of the element 2. Flanges 40 have a shaped recess 8 into which membrane 10 is seated so that the flanges 60 and 62 sit on the outside of the element mounting plate. When these are bolted together adjacent flanges 60 and 62 engage on adjacent elements 2 and are, by friction and compressive forces, held such that they do not move.

The membrane 10 can be manufactured from any suitable material including Kevlar, Neoprene, polyurethane, Natural rubber or any appropriate wear resisting material.

When the membrane 10 is compressed or moved to the closed position, it is the central portion 58 which compresses in the direction of arrows 70. The arrows 70 are parallel to

the minor axis 66. As fluid pressure is being applied, the membrane 10 will compress along the line of least resistance which is in the direction of arrows 70. By this compressing the 2 sides of the membrane 10, namely sides 72, 74, 76 and 78 (see figure 9), the adjacent sides 72, 76, 74 and 78 are only moved through a comparatively small angle until further
 5 movement is prevented. Thus sides 72, 74, 76 and 78 move from their angled position to an approximately horizontal position at the centre of membrane 10, as equal pressure is applied on all sides. Obviously, the membrane sides 72, 74, 76 and 78 only meet (as is depicted in figure 11 and 12) in the central portions 58 of the membrane 10 whereas they do not meet at the ends of the elements 2, when pressure is applied.

10 Alternative to having the flanges 60 and 62 engage by friction, when adjacent elements 2, are joined, the flanges 60 and 62 can have a more positive method of securing such as that illustrated in figure 10.

In figure 10 the shaped recess 8 is encircled by a groove 80 into which is placed an O ring or solid round member 82. Or alternatively, a raised projection 84 can be welded or formed
 15 around recess 8 on mounting plate 6. The flange 60 or 62 has a similarly positioned recess 85 which is moulded during the moulding process by the inclusion of a tube 86. When a like arrangement is forced together by bolting through the flange 40 the projection 82 is forced to deform the membrane by squashing the recess 85. This provides an interlocking of the flanges 60 and 62 with the mounting plate 6 and flange 40. This will help to resist an
 20 inward pulling effect in the direction of arrow 88, by providing a greater clamping force than with friction alone. The inward pulling effect in the direction of arrows 88 results from the compression of membrane 10.

A further alternative is for a longer flange 60 and 62 to be moulded with the inclusion of holes in register with bolt holes in flange 40.

25 An alternative to the use of bolts to mount adjacent elements 2 is a circumferential clamp which is tapered on both sides (not illustrated) which engages similarly tapered flanges (not illustrated) so that when the clamp is placed around two adjacent flanges, and secured, the respective tapered faces will interact to force the flanges together with a sufficient longitudinal clamping force.

30 In figure 9 is a circle 90 illustrated in phantom line. Circle 90 is the effective diameter through the pump assembly when all of the membranes 10 are in the open or uncompressed condition. It also gives an indication of the size of the inlet and outlet pipes for the pumps of figures 5 or 6. The same is true if the assembly is used as a valve or mixing apparatus.

By activating the actuating cylinders 18 of the assembly 38 or 54 of figures 5 or 6
 35 respectively, a valve mechanism results, or if activated in a sequential fashion, a peristaltic pumping action or an action mixing can be achieved. Illustrated in figure 11 is an

EXAMPLE A of a pumping sequence which will allow the pumps of figs 5 and 6 to operate.

In figure 11 the following reference numerals indicate a corresponding description:

Reference	Stage
Numeral	Description
92	No flow
94	1st stage fill
96	2nd stage fill
98	3rd state fill
100	4th stage fill
102	Enclosure
104	1st stage effect
106	1st stage fill and 2nd stage fill
108	2nd stage fill and 3rd stage eject
110	3rd stage fill and final eject
114	Go to step at reference numeral 102. Enclosure and repeat.

At 92 in figure 11 all of the membranes, which have been numbered 116, 118, 120, 122, 124, and 126 from left to right, are in closed position. At the first stage of filling 94, membrane 116 is deactivated allowing a flowable material to enter the pumping chamber. Each of the pump elements 118 to 124 are then sequentially opened whilst element 126 remains shut until such time as membrane 116 is also shut, and membranes 118 to 124 are in the open condition. As illustrated in stage 102 membranes 116 and 126 act as valves. In stage 104 the first stage of ejection takes place which sees the simultaneous opening of membrane 126 whilst at the same time membrane 118 is actuated to the closed position. In stage 106 the first stage of the filling process occurs whilst second stage of the ejection process simultaneously occurs. Thus in stage 106 the membrane 116 is opened whilst membrane 120 is closed. This sequence continues to operate whereby one membrane on the down stream side is activated whilst a membrane on the upstream side is simultaneously or sequentially deactivated. In this way there is always at least one membrane of the six in a activated or deformed state.

The pumping sequence can be varied to produce a pumping action. Thus other alternative sequences can include:

EXAMPLE B (where "C" indicates a closed or deformed membrane, whilst "O" indicates an open or undeformed membrane)

membrane	→	116	118	120	122	124	126
stages	1st	C	C	C	C	C	C
	2nd	O	C	C	C	C	C
	3rd	C	O	C	C	C	C
	4th	C	C	O	C	C	C
	5th	C	C	C	O	C	C
	6th	C	C	C	C	O	C
	7th	C	C	C	C	C	O

- 5 In this sequence the downstream membrane is opened before the previously opened membrane is re closed. The membrane 116 opening in the first stage is self primed by virtue of the suction produced when membrane 116 opens.

EXAMPLE C

membrane	→	116	118	120	122	124	126
stages	1st	O	O	O	O	O	O
	2nd	C	O	O	O	O	O
	3rd	C	C	O	O	O	O
	4th	C	C	C	O	O	O
	5th	C	C	C	C	O	O
	6th	C	C	C	C	C	O
	7th	C	C	C	C	C	C

- 10 In this example the first stage is either primed, or the suction produced by the opening of a closed membrane draws material through if the first stage is where all membranes are closed.

EXAMPLE D

membrane	→	116	118	120	122	124	126
stages	1st	O	O	O	O	O	O
	2nd	O	O	O	C	O	O
	3rd	C	O	O	O	C	O
	4th	O	C	O	O	O	O
	5th	O	O	C	O	O	O
	6th	O	O	O	C	O	O
	7th	C	O	O	O	C	O

EXAMPLE E

membrane	→	116	118	120	122	124	126
stages	1st	O	O	O	O	O	O
	2nd	C	C	C	O	O	O
	3rd	O	C	C	C	O	O
	4th	O	O	C	C	C	O
	5th	O	O	O	C	C	C
	6th	C	O	O	O	C	C
	7th	C	C	O	O	O	C
	8th	C	C	C	O	O	O

EXAMPLE F

membrane	→	116	118	120	122	124	126
stages	1st	C	C	C	C	C	C
	2nd	O	C	C	C	C	C
	3rd	O	O	C	C	C	C
	4th	C	O	O	C	C	C
	5th	C	C	O	O	C	C
	6th	C	C	C	O	O	C
	7th	C	C	C	C	O	O

The most efficient running of the pump will be when only a minimum number of pump membranes 116 to 126 are in the closed or compressed state at any one time.

5 The minimum number of membranes in compressed state occurs in the following sequence:

EXAMPLE G

membrane	→	116	118	120	122	124	126
stages	1st	O	O	O	O	O	O
	2nd	C	O	O	O	O	O
	3rd	O	C	O	O	O	O
	4th	O	O	C	O	O	O
	5th	O	O	O	C	O	O
	6th	O	O	O	O	C	O
	7th	O	O	O	O	O	C
	8th	C	O	O	O	O	O

However the operation of such a sequence as in example G will depend upon the lead and lag time of the control and actuation mechanisms and circuitry. Thus if the speed of closure is greater than the speed of opening, a discharge from the pump will result.

- 10 The compression and decompression of the membranes, can be controlled by microprocessor to conveniently and efficiently control the compression sequences. In the embodiments disclosed the actuation of the piston 14 is by means of a hydraulic actuating cylinder 18. However, this actuator cylinder 18 can be replaced by any suitable type of

actuating mechanism such as mechanical, pneumatic, or even electromagnetic means such as by means of solenoid type mechanisms.

Illustrated in figure 12 are the possible sequencing of membranes 116 to 126 which will allow an assembly, as illustrated in figures 5 or 6, to be utilised as a mixing apparatus.

- 5 For figure 12 the following reference numerals indicate a corresponding description:

Reference	Stage
Numeral	Description
93	No flow
95	1st stage fill
97	2nd stage fill
99	3rd stage fill
101	Enclosure
103	1st stage mix
105	1st stage mix
107	3rd stage mix
109	4th stage mix
111	1st stage eject
113	2nd stage eject and 1st stage eject
115	Go to step at reference numeral 97 and repeat

Numerals 93 to 99 illustrate a fill sequence similar to that of figure 11. However, it will be noted that from stage 5 [101] there are three (3) membranes activated before the mixing stages begin. These membranes are membranes 116 and 126 which act as valve membranes and membrane 124 which is also activated to provide space to allow for the movement of a non-homogeneous flowable material which is enclosed, to move in a reciprocating fashion between the "valve" membranes 116 and 126.

Thus in the first stage of mixing 103 membrane 120 is activated whilst membrane 124 is deactivated. This can be done either simultaneously or sequentially. This will agitate the captured material by forcing it into two directions. At second stage of mixing 105, membrane 122 is activated whilst membrane 120 is deactivated again forcing the enclosed material into two directions. At the third stage of mixing 107, the membrane 118 is

activated whilst membrane 122 is deactivated, in this instance forcing the material in a single direction. Finally the fourth stage of mixing 104, entails the deactivation of membrane 118 and the reactivation of membrane 124 which will force the material in a single direction, in this case upstream. The final stages 111 and 113 of the mixing sequence
5 are the ejection stages which are similar to the initial filling stages 95, 97, 99 and 101. The actual mixing stages 103, 105, 107 and 109 can be varied according to the desired results as the activation and deactivation of membranes 116, 118, 120, 122, 124 and 26 need not actually take place in the sequence mentioned.

In the pumping action produced by assemblies 38 and 54, a full closing of the membrane
10 need not occur. The pumps 38 or 54 can still produce flow if the most upstream membrane (116) is closed and the other membranes are sequentially compressed, not to closing, but by a fraction of the compression required to produce a closed passage. The flow produced by partial compression will not be as great as compared to full compression, but material flow is still produced. The flow produced may be likened to a compression
15 wave.

Illustrated in figure 13 is a membrane having an approximately circular cross section which is similar to those membranes as utilised in the prior art. Overlaying this is a cross section of a substantially elliptical membrane 130, showing the respective configurations in the uncompressed state. The membrane 130 has minor axis 132 and major axis 134.

20 In figures 14, 15 and 16 are alternative embodiments of the membrane 10. The ellipse 130 of figure 13, has a minor axis 132 and a major axis 134 and the deformation of the membrane occurs along the minor axis 136. Figure 14 illustrates a substantially teardrop shape membrane 140 which allows formation of the membrane 140 by a planar polymeric sheet folded over. It has minor axis 142 and major axis 144. Figure 15 illustrates a
25 substantially elliptical shape membrane 146 having a larger major axis 148, or smaller minor axis 136, when compared with minor axis 132 the ellipse 130 of Figure 14. Figure 16 illustrates a substantially elliptical or circular shape membrane 152 with pointed ends being made up of two part circumferences of a circle. This shape helps to further minimise the amount of movement which occurs at the ends of the membrane. The membrane 152 of
30 figure 16 can be fabricated from two flat sheets or two part circular members. By the provision of a major axis 154 and minor axis 156 on the membrane 152 when in an uncompressed state, a natural line of weakness or minimum resistance to hydrostatic pressure exerted on the membrane is provided. This controls the direction in which deformation will occur. With a circular cross section, this deformation cannot be controlled
35 when hydrostatic pressure is used to produce deformation.

Pump assemblies built in accordance with the present invention and figures 1 to 16 provide a clear through passage as is illustrated in figure 6 and indicated by elements 52. This feature allows the maximum pumping power, required for particular slurry pumping duties, to be split. Maximum required pumping power is determined based upon worst case scenarios, but normal pumping duties only require a fraction of this maximum power. The maximum power must be present, for example, if high viscosity slurries enter the system and require pumping.

As the pump assemblies built in accordance with this invention and figures 1 to 16 provide a clear passage when the membranes are in an undeformed state, this allows a bank or assembly of pump elements to be assembled with for example two spares already in serial connection. Thus the assemblies of figures 5 or 6 may have eight pump elements in series connection, with only six of these being in operation during normal duty. The other two can be brought into operation in the event of breakdown or to conduct routine maintenance, or to boost the effort of the other membranes.

Thus if maximum pumping requires 1500kw of pumping power based upon conventional rotational, piston or displacement pumps, then utilising more efficient pumping assemblies of the present invention and figures 1 to 16 will allow a 600kw peristaltic pump to be installed at the beginning of the pipe line, with an auxiliary 600kw connected in series and not used until required. These efficiencies and splitting of pump locations could save up to 30% of costs of conventional systems and after advantages of having a "spare" already in line.

Illustrated in figure 17 is a pump assembly 160 including a single tube shape membrane 162 which extends across the whole length of the pump assembly 160. The membrane 162 can be constructed from elastomeric or polymeric materials. Whilst some elasticity in the membrane 162 may be present, elasticity is not an essential property of the membrane 162. At spaced locations on the membrane 162 are a series of plate actuators 164 which are bonded to the membrane 162. The plate actuators 164 are connected by means of a member 166 by a suitable pivot point 168 (or other pin jointed arrangement) to a support structure 170 located, in this instance above the plate actuator 164. The support structure 170 supports the whole weight of the plate actuators 164 and the membrane 162, in view of the plate actuators 164 being bonded to the membrane 162. In front elevation as illustrated in figure 18 there will be seen two plate actuators 164 at each location, one on either side of the membrane 162. A central portion of the plate actuators 164 is pivotally connected to an actuation bar 172. The actuation bar 172 can either directly or indirectly be made to translate.

The pump assembly 160 is illustrated in figure 20. It operates by means of magnetic attraction and repulsion produced by electromagnetic coils 174 and 176 located adjacent the plate actuators 164. The actuation bars 172 are here illustrated as passing through the electromagnetic coils 174 and 176. The electromagnetic coils 174 and 176, by carrying
5 current in one direction, will move the actuator bars 172 so that the membrane 162 is compressed. This compression can be controlled to occur at a selective location. See for example figure 19 wherein the plate actuators 164 at position 180 are shown compressing membrane 162. By changing the direction of current in electromagnetic coils 174 and 176 the plate actuators 164 by attachment to the actuator bars 172, are then moved towards the
10 electromagnetic coils 174 and 176 and thus decompress the membrane 162.

Preferably the membrane 162 is made of a polymer which has magnetic isolating capabilities. This prevents the interaction between respective magnetic fields on either side of the membrane 162.

The pump assembly 160 utilises a membrane 162 which is constructed with a major and
15 minor axis. In figure 18 this is illustrated as an elliptical shaped membrane 162. By providing an major and minor axis, the amount of deflection required to compress the membrane 162 is greatly reduced by comparison to circular membranes. Other alternative shapes are illustrated in figures 13, 14 15 and 16.

To improve the effectiveness of the pump assembly 160 an electromagnetic coil can be
20 located in or on the plate actuators 164. The electromagnetic coil on each plate actuator 164 can be made to carry different polarity to each other and identical to the respective electromagnetic coils 174 and 176, thus allowing the plate actuators 164 to attract each other at the same time as being repulsed by the outside electromagnetic coils 174 and 176. In this situation, the membrane 162 will be able to transmit or not effect the magnetic
25 forces between the plate actuators 164.

By the sequential compressing and decompressing of the plate actuators 164 along positions 178, 180, 182, 184, 186 and 188 movement of a substance contained within the membrane 162 will be effected by the alternating compression and decompression of plate actuators 164.

30 Illustrated in figure 21 is a similar arrangement to that of figure 17 to figure 20 except that instead of electromagnetic coils 174 and 176 acting to compress and decompress the membrane 162, an oscillation linkage 190 and 192 is provided to produce alternate compression and decompression of the elastomeric tube by the bringing together of the plate actuators 164 as the oscillation linkage 190 rotates in the direction of arrows 192, by
35 the link member 194 being pivotally connected to 176. The plate actuators 164 are moved inwards and outwards to produce the necessary compression and decompression. This

linkage provides a positive force in the decompression direction as the plate actuator 164 is bonded to the membrane 162 and does not rely upon the elastomeric nature of the membrane 162 to act as a spring and thereby return the plate actuators 164 to their starting position.

- 5 Figure 22 illustrates a pneumatic or hydraulic or air cylinder which can be substituted for the oscillation linkage 190. Such a cylinder will provide the requisite application of force against the plate actuators 164, via the actuator bar 172, in both the positive and negative directions.

10 Illustrated in figure 23 is an alternative embodiment whereby the membrane 162 is connected to a support structure at location 196 and is connected to an plate actuator 164 on the diametrically opposite side. In this arrangement, the length of travel of the plate actuator 164 and actuation bar 172 is twice that of the other embodiments, but the net travel of the sides of the membrane 162 relative to the centre portion of the membrane 162 is the same as in other embodiments.

- 15 The embodiments illustrated in figures 17 to figure 20, figure 21, and figure 22 can be set to produce either total or partial closure, or made to produce a variable extent of closure of the membrane 162. Partial closure will still produce translation of material through the length of the membrane 162. If partial closure or variable closure is produced, when water for example containing fish is pumped, the fish are not crushed to death or acted upon by
20 impellers and other rotating equipment such as exist in the prior art. The partial closure system is also effective when critical particles such as for example a slurry of fruit or other food is passing through the system. The partial or variable closure of the membrane 162 will produce motion of the material contained by the membrane 162, by the production of a directional or compression wave.

- 25 The electromagnetic coils 174 and 176 and the actuator bars 172 function in the same way as a solenoid. This arrangement can be modified so that the electromagnetic coils 174 and 176 generate a magnetic field. With similar electromagnetic coils mounted on the plate actuators 164, the actuator bar 172 could be deleted. The compression and decompression of the membrane 162 will occur by the attraction and repulsion of the plate actuators 164
30 and their respective electromagnetic coils, relative to the electromagnetic coils 174 and 176. By also making the membrane 162 such that it does not magnetically insulate, the plate actuators 164, if given different polarity will attract each other whilst at the same time as being repelled by the electromagnetic coils 174 and 176, which carry a like magnetic field to the respective plate actuators 164. By then reversing the current in one plate
35 actuator 164 and one of the electromagnetic coils 174 and 176 (the current direction should be changed in the coil associated with the plate actuator 164 which does not have its

current reversed), the plate actuators 164 will be repelled from each other whilst at the same time being attracted to the electromagnetic coils 174 and 176. In this way compression and decompression can be produced.

CLAIMS

1. A membrane for a flowable material handling device comprising at least one flow chamber which is defined by the membrane, the membrane being adapted to be deformed or compressed, thereby reducing the volume of the chamber, characterised in that the chamber, in an uncompressed state, has a cross section which comprises a major and minor axis, the chamber being deformed or compressed in a direction perpendicular to the major axis or parallel to the minor axis.
2. A membrane having inner and outer surfaces, the inner surface defining a fluid passage whilst said outer surface being adapted to engage compression means to deform or compress said fluid passage, characterised in that said fluid passage when uncompressed has in cross section a first axis in the direction of which compression occurs and a second axis crossing said first axis, wherein said second axis is longer than said first axis.
3. A membrane as claimed in claim 1 or 2, wherein said membrane, has a flange at each end enabling said membrane to be secured into a housing.
4. A membrane as claimed in claim 1 or 2, wherein the membrane has flanges at each end which include means adapted to seal or hold stationary adjacent membranes, with respect to each other.
5. A membrane as claimed in claim 3 or 4 wherein the flanges also include a formation to mate with a complementary formation on a housing to hold the flange in place relative to the housing.
6. A membrane as claimed in any one of the preceding claims wherein said membrane is manufactured from Kevlar or neoprene or polyurethane or natural rubber or a composite material.
7. A membrane as claimed in an one of the preceding claims wherein the cross section of the membrane, in uncompressed state, is substantially elliptical, or substantially diamond, or substantially teardrop or partially elliptical, or partially circular.
8. A flowable material handling device including a membrane as claimed in any of the preceding claims.
9. A flowable material handling device as claimed in claim 8, wherein said device is a pump or a valve or a mining apparatus.
10. A flowable material handling assembly comprising an element having a deformable membrane which defines a passage through said element wherein pressure applied

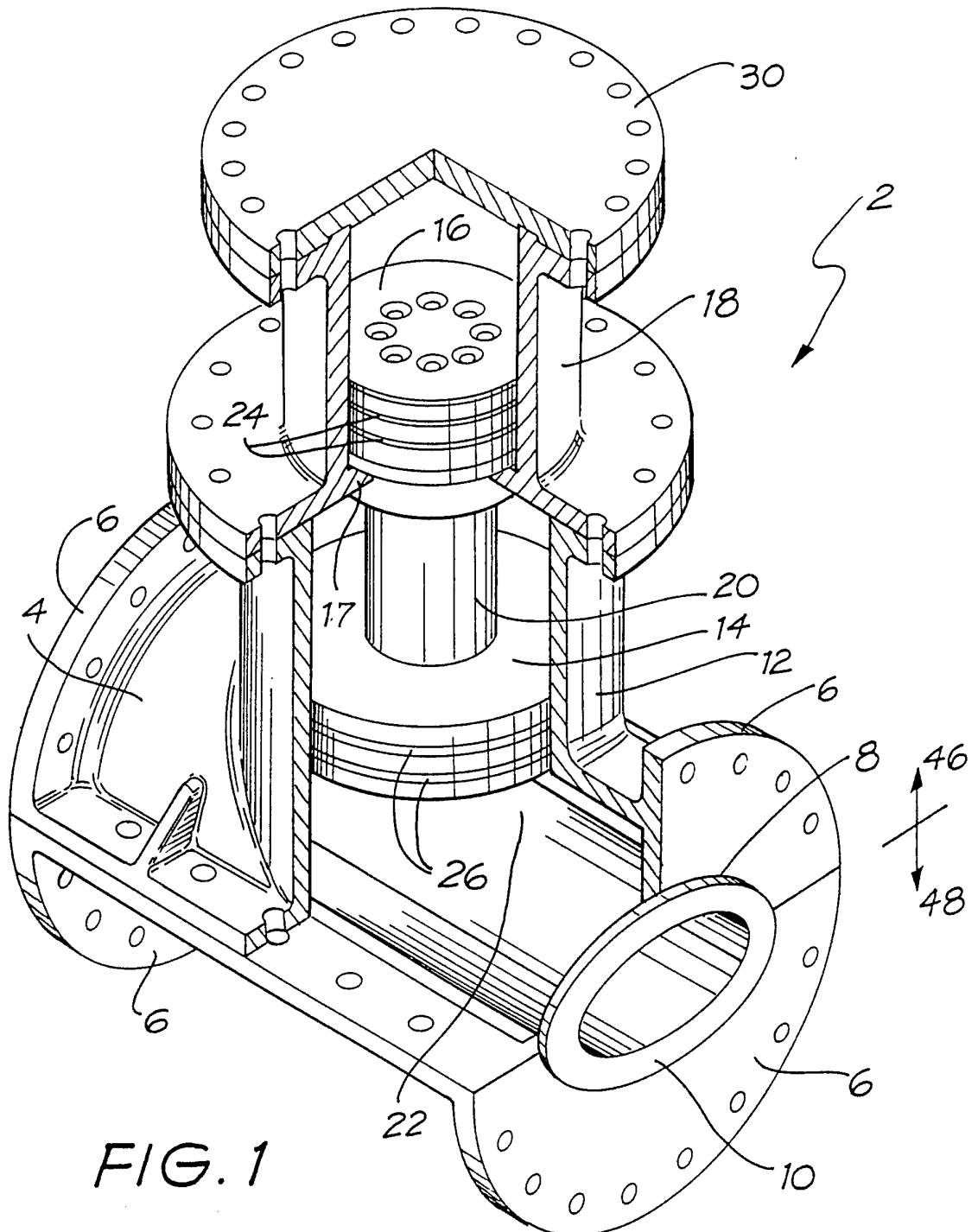
to compress the membrane produces a pre-determined volume change in said membrane.

11. A flowable material handling assembly as claimed in claim 10 wherein pressure applied to deform the membrane is applied by means of an incompressible fluid.
- 5 12. A flowable material handling assembly as claimed in claim 11 wherein the incompressible fluid is pressurised by a piston means, which piston means travels a pre-determined distance and the maximum travel of said piston means provides a pressure which is bearable by said membrane.
- 10 13. A flowable material handling assembly as claimed in any one of claims 10 to 12 wherein said piston means is moved by a piston actuation means.
14. A flowable material handling assembly as claimed in any one of claims 10 to 13 wherein either said piston means is limited in its travel or when said piston means is moved by a piston actuation means, the piston actuation means is limited in its travel, thereby limiting the movement of said piston means.
- 15 15. A flowable material handling assembly as claimed in any one of claims 12, 13 or 14 wherein hydraulic pressure is applied to provide movement to the piston means
16. A flowable material handling assembly as claimed in claim 12 wherein the piston actuation means either a pneumatic or hydraulic powered ram, mechanical means or electromagnetic means.
- 20 17. A flowable material handling assembly as claimed in claim 15 or 16 wherein when the piston actuation means is a hydraulic means, a control valve is provided to direct fluid to a low pressure side of a hydraulic actuator.
18. A flowable material handling assembly is claimed in any one of claims 10 to 17, wherein the membrane is a shape having a major and minor axis in cross section
25 when in an undeformed state.
19. A flowable material handling assembly as claimed in any one of claims 10 to 18 wherein the cross section of the membrane is substantially elliptical or substantially diamond or substantially teardrop or partially elliptical or partially circular in shape.
20. A flowable material handling assembly as claimed in any one of claims 10 to 19,
30 wherein said assembly is a pump or a valve or a mixing apparatus.
21. A flowable material handling assembly comprising at least one membrane having at least one actuation means associated there with said actuation means forcing together the sides of the membrane to thereby compress a material contained in the

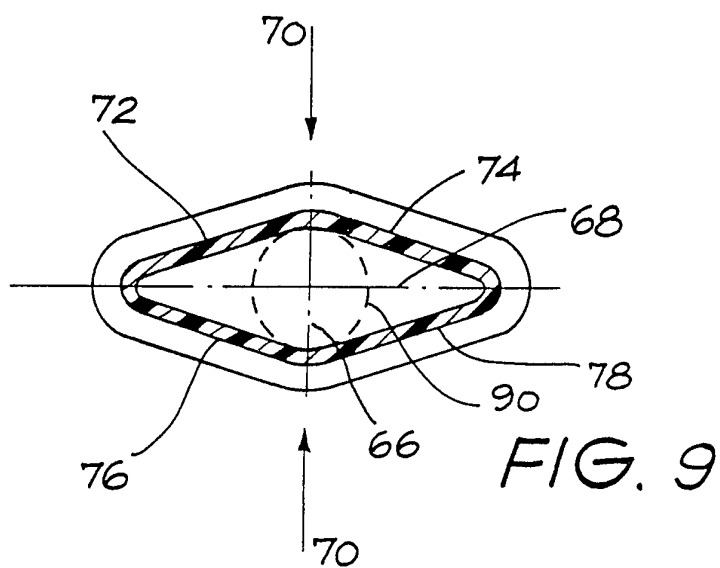
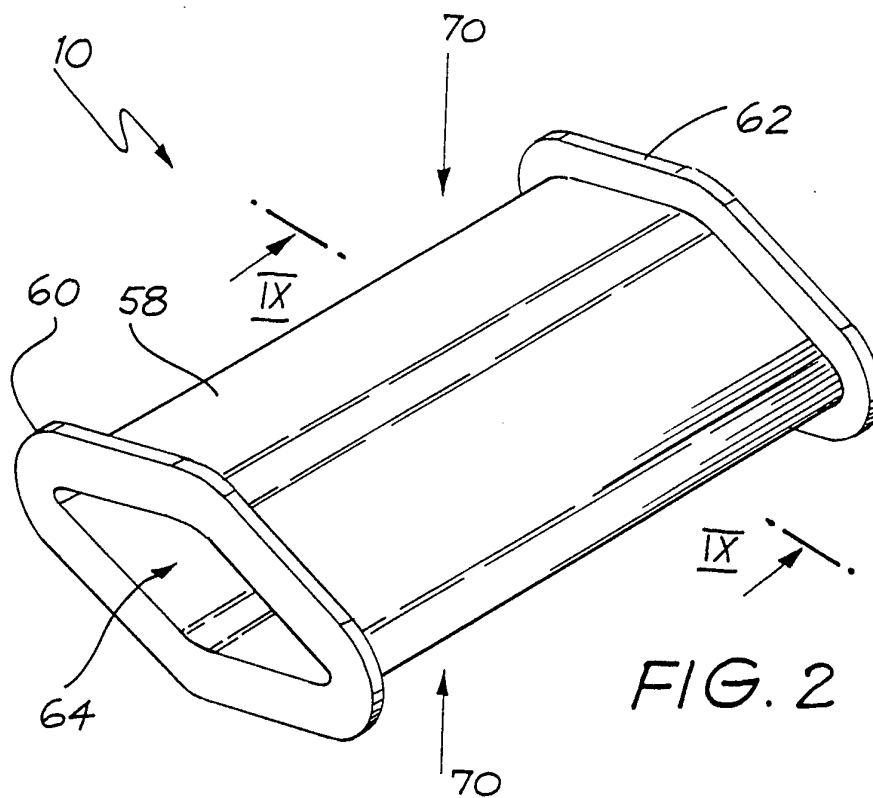
membrane and positively move apart the sides of the membrane to thereby decompress the membrane or its internal volume.

22. A flowable material handling assembly including a substantially tubular shaped membrane having connected thereto at least one actuation means, the actuation means having two components located at opposite portions of the membrane, the two components of the actuation means being adapted to move towards and away from each other thereby selectively compressing and decompressing the membrane.
23. A flowable material handling assembly as claimed in claim 21 or 22, whereby when more than one membrane is used, one set of actuation means is utilised per membrane.
24. A flowable material handling assembly as claimed in claim 21 or 22, whereby when one membrane is used, more than one actuation means is utilised on the membrane, to form a flowable material handling device.
25. A flowable material handling assembly as claimed in any one of claims 21 to 24, whereby the actuation means is comprised of a set of actuation means.
26. A flowable material handling assembly as claimed in claim 25, whereby a set of actuation means is made up of opposing actuation means configured to compress and decompress the membrane when required.
27. A flowable material handling assembly as claimed in any one of claims 21 to 24, whereby the actuation means is a single actuation means which cooperates with a stationary surface so configured as to compress and decompress the membrane when required.
28. A flowable material handling assembly as claimed in any one of claims 21 to 27, wherein the actuation means are bonded plate actuators activated by electromagnetic coil, or mechanical oscillatory drive, or hydraulic, air or pneumatic cylinder or other direct mechanical link, to thereby provide the decompression force as well as the compression force.
29. A flowable material handling assembly as claimed in any one of claims 21 to 28 whereby when the membrane or membranes are compressed and decompressed in a predetermined sequential fashion the membrane or membranes can act as a pumping member or mixing device.

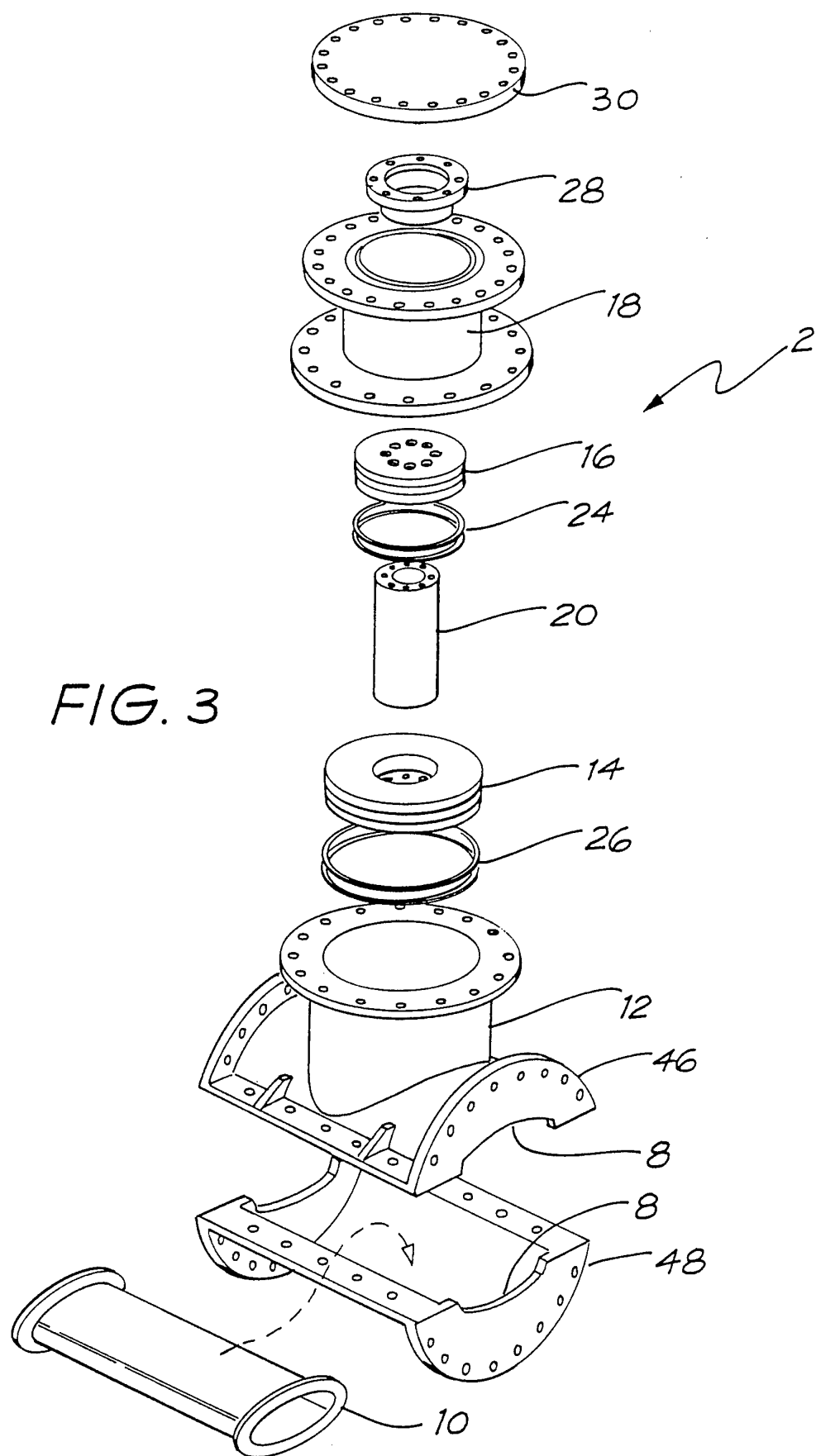
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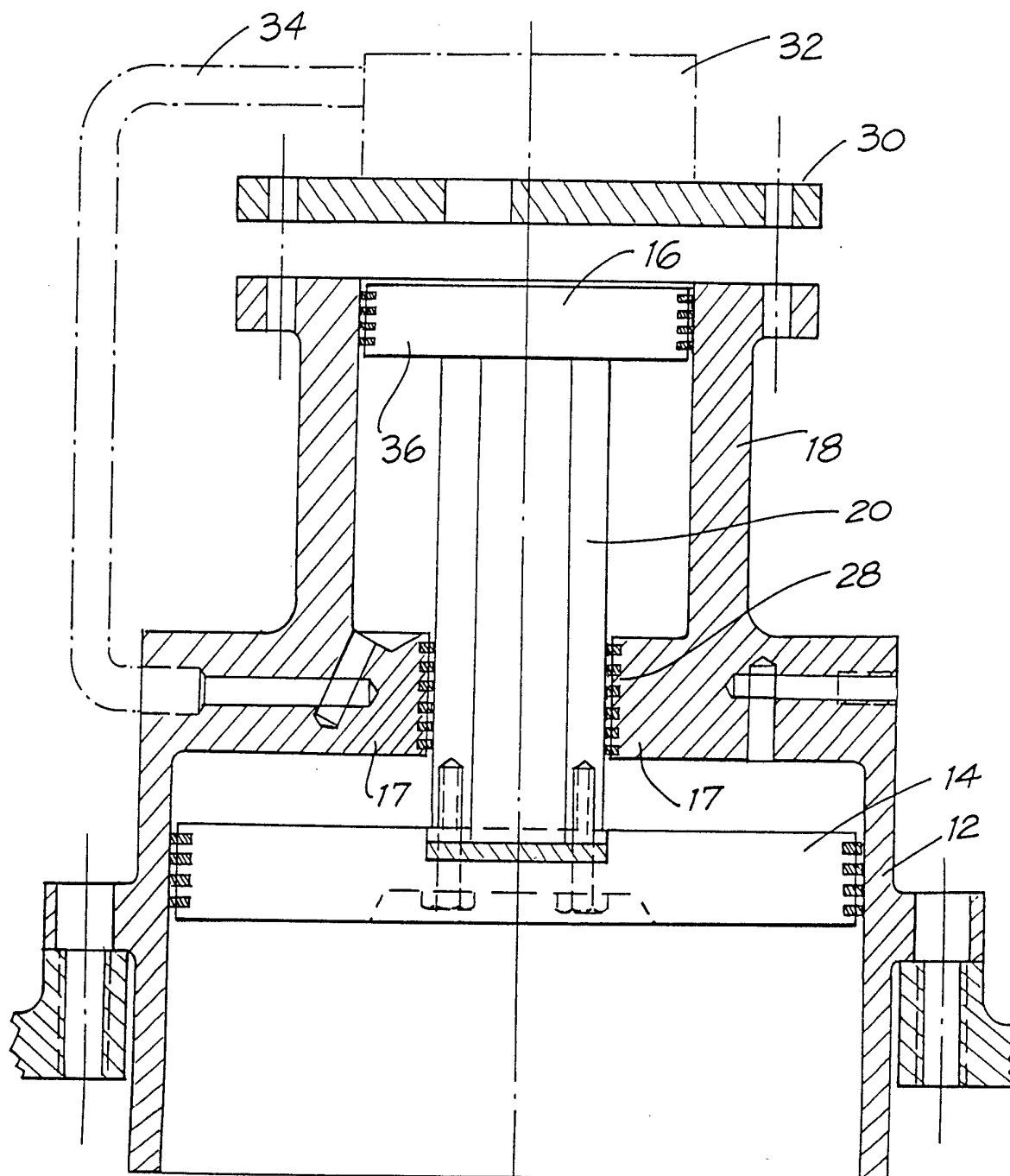


FIG. 4

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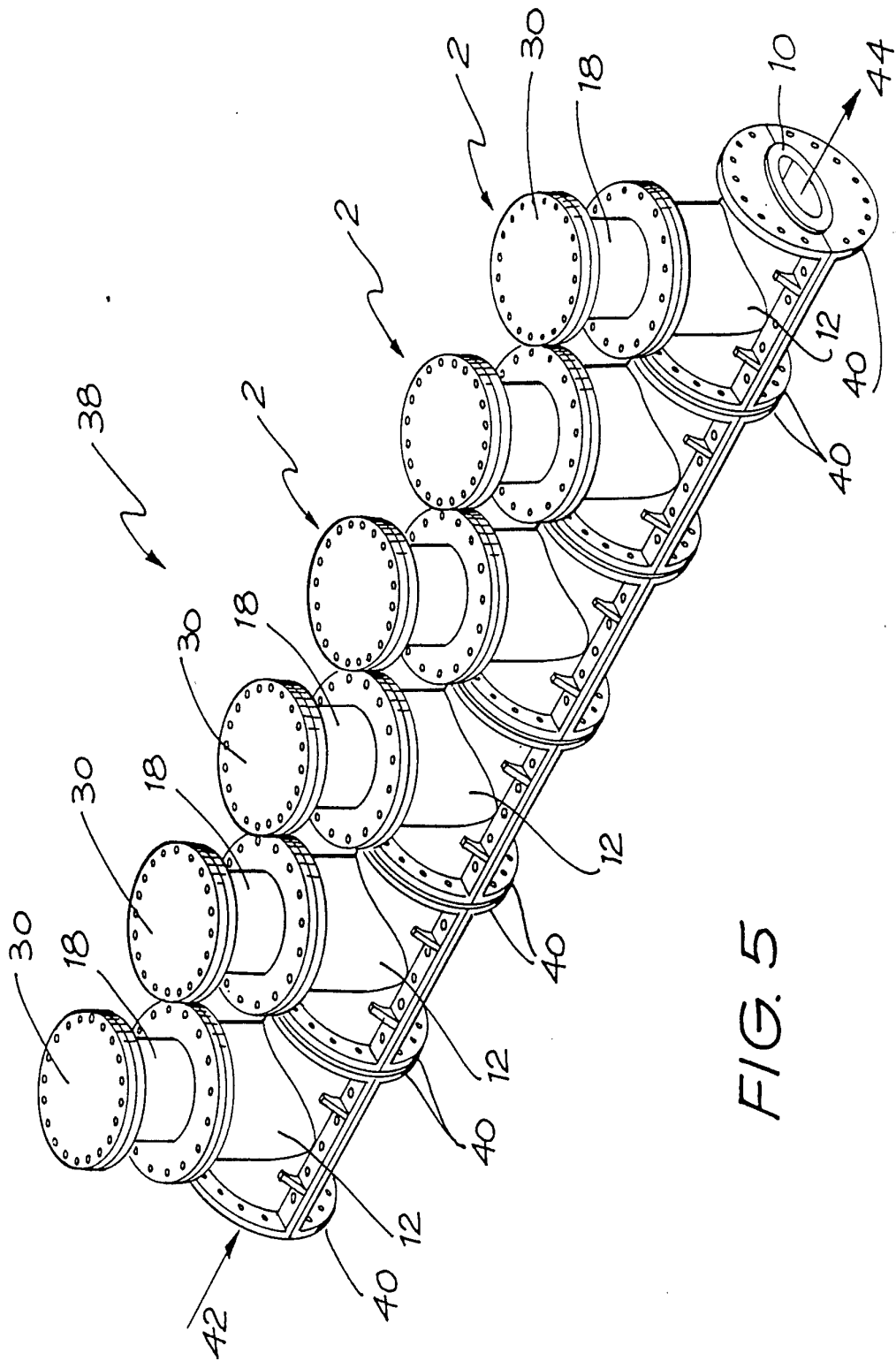


FIG. 5

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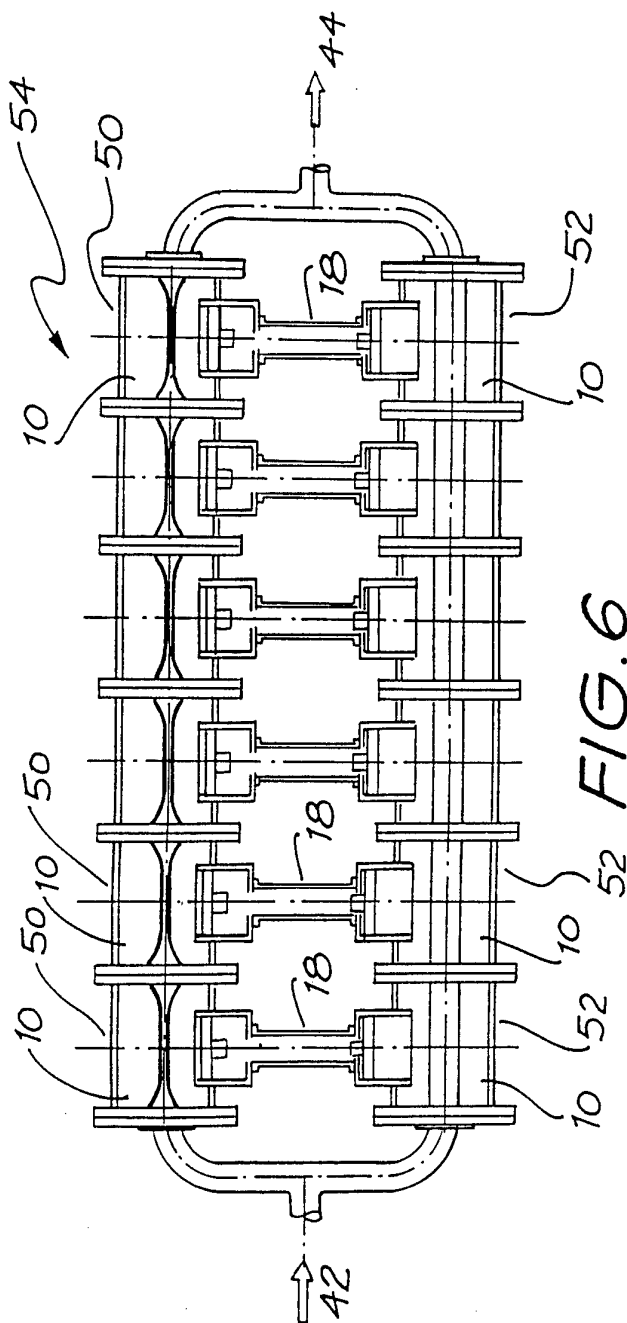


FIG. 6

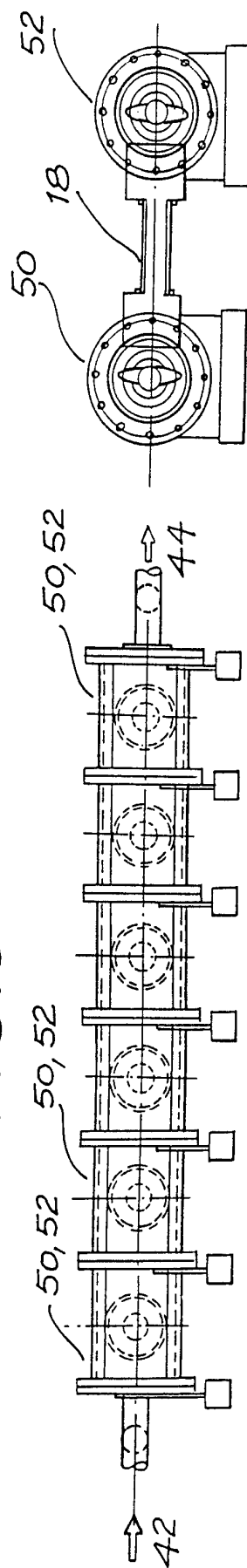
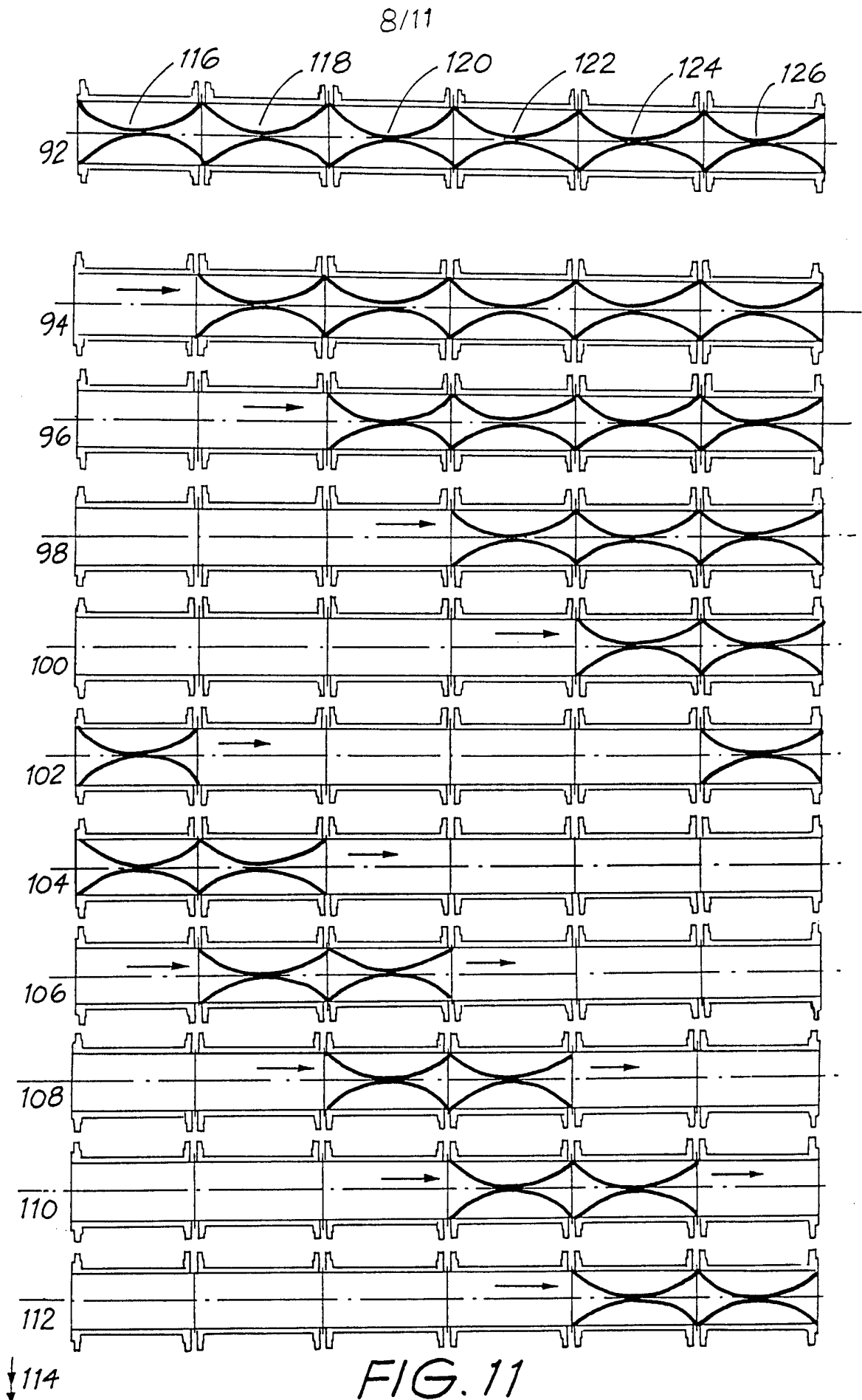


FIG. 7

FIG. 8



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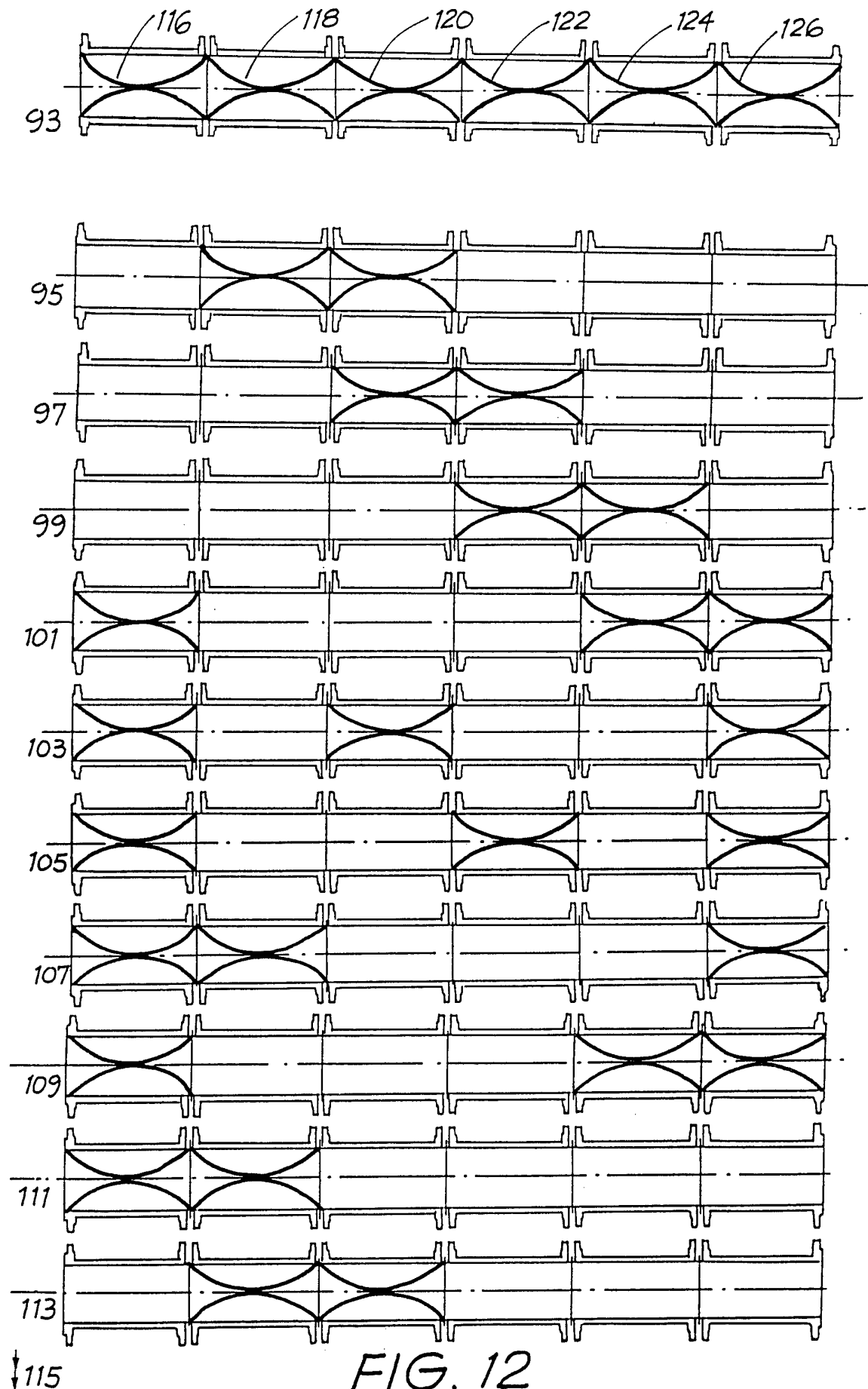
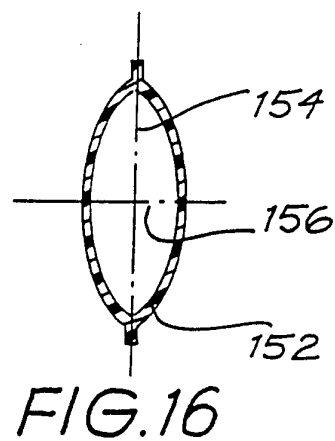
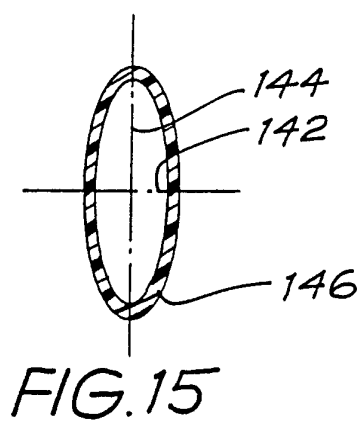
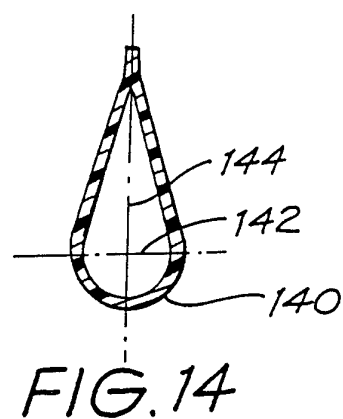
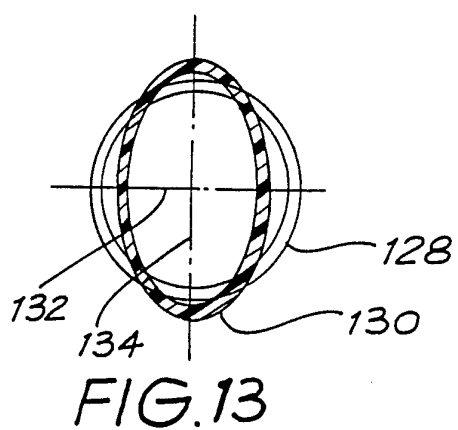


FIG. 12



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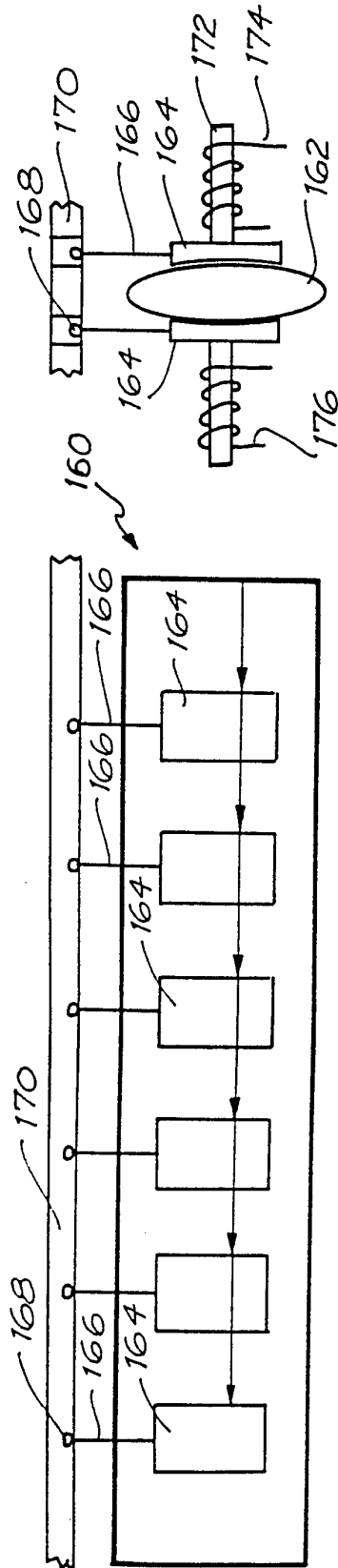


FIG. 17

FIG. 18

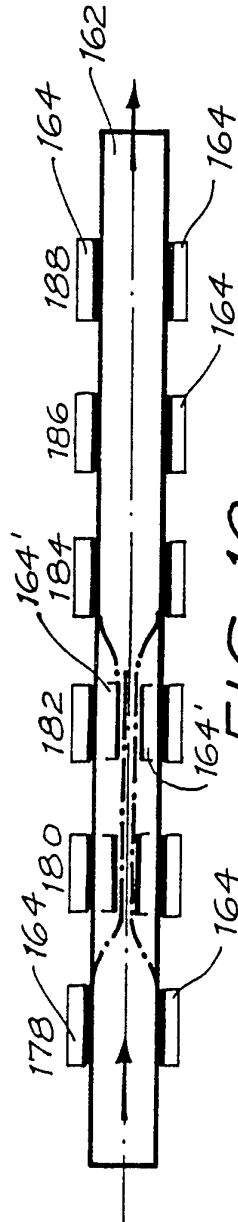


FIG. 19

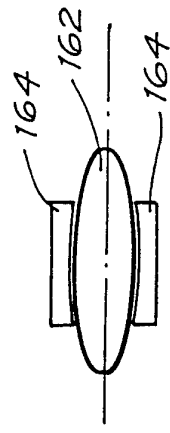


FIG. 20

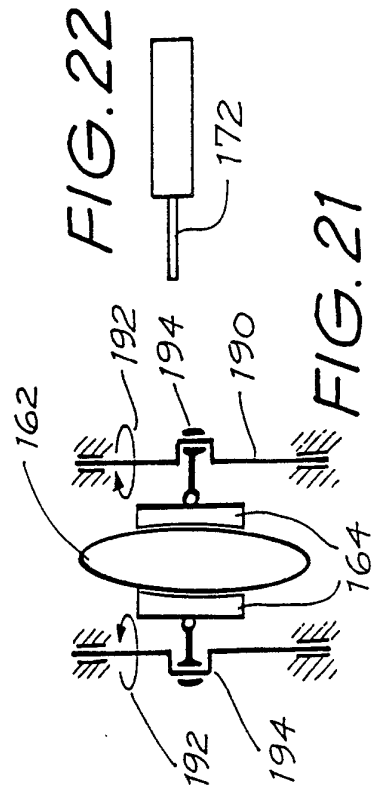


FIG. 21

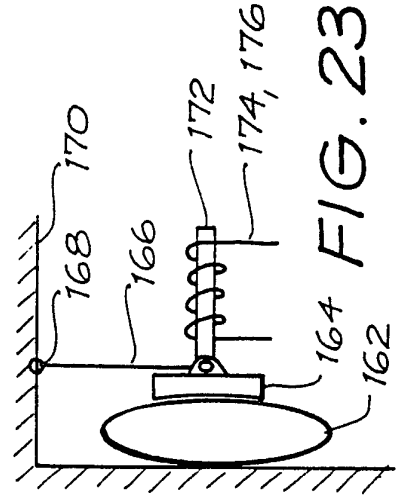


FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 94/00696

A. CLASSIFICATION OF SUBJECT MATTERInt. Cl.⁶ F04B 43/08, 43/107, 43/113, 43/12, 43/14

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC : F04B 43/08, 43/10, 43/107, 43/113, 43/12, 43/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as aboveElectronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT
JAPIO**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
X	US,A, 4102612 (RITTER) 25 July 1978 (27.07.78) column 3, line 18 - column 4, line 3	1-3, 5, 7-9
Y	column 3, line 18 - column 4, line 3	4
X	US,A, 4936760 (WILLIAMS) 26 June 1990 (26.06.90) column 3, line 50 - column 5, line 68	1-2, 6-10, 21-22, 28-29
X	DE,A, 2530440 (DAIWA MACHINERY MANUFACTURE LTD.) 29 January 1976 (29.01.76) page 3, line 15 - page 6, line 7	1-3, 5-9
Y	page 3, line 15 - page 6, line 7	4

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

* Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

document member of the same patent family

Date of the actual completion of the international search
24 January 1995 (24.01.95)

Date of mailing of the international search report

7 Feb 1995 (7.2.95)

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate of the relevant passages	Relevant to Claim No.
X	WO,A, 89/09340 (RIGBUY) 5 October 1989 (05.10.89) page 3, line 12 - page 5, line 13	10-11
X	GB,A, 1352843 (JONES) 15 May 1974 (15.05.74) page 3, lines 91-119 and page 4, lines 6-24	10, 21-22, 24-26
X	NL,A, 9100929 (BUITENDIJK HOLDING B.V.) 16 December 1992 (16.12.92) drawing figures 1, 3 and 4	10-17, 20
X	GB,A, 1409412 (MILTON ROY COMPANY) 8 October 1975 (08.10.75) page 1, line 45 - page 2, line 105	10-14, 16, 18-20
X	US,A, 4178133 (RAWICKI) 11 December 1979 (11.12.79) drawing figure 1	10-14, 16
X	Derwent Abstract Accession NO. 92-266899/32, Class Q56, SU,A, 1687866 (POLYMERIC MATERIALS RES. INST.) 30 October 1991 (30.10.91) abstract	21, 24-25, 27, 29
X	DE,A, 2708277 (NIKKISO EIKO CO. LTD.) 31 August 1978 (31.08.78) page 10, line 3 - page 11, line 18	21-22, 27-29
X	GB,A, 2179404 (ROBERTSON) 4 March 1987 (04.03.87) page 3, line 62 - page 5, line 9	21-22, 24-29
X	FR,A, 2640698 (ECOLE NATIONALE SUPERIEURE DES ARTS ET INDUSTRIES DE STRASBOURG) 22 June 1990 (22.06.90) page 12, line 6 - page 13, line 32; page 6, lines 15-21 and drawing figures 4-5	10-17, 20, 23, 25-26, 29
Y	drawing figure 11	4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 94/00696

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

Patent Document Cited in Search Report				Patent Family Member			
WO	8909340	AU	32368/89				
GB	1409412	DE	2421487	FR	2230878	JP	50020304
DE	2530149	US	4102612				
DE	2530440	FR	2277998	JP	51086811		
END OF ANNEX							

Box II (continued)

1. Claims 1-9 are directed to a membrane for a flowable material handling device, the membrane defining a flow chamber, where "the chamber cross-section comprises two axes and compression of the chamber is parallel to the shorter of the two axes" is considered as the first special technical feature.
2. Claims 10-20 are directed to a flowable material handling assembly, wherein "an element having a deformable membrane which defines a passage therethrough and pressure applied to compress the membrane produces a pre-determined volume change in said membrane" is considered as the second special technical feature.
3. Claims 21-29 are directed to a flowable material handling assembly having a membrane wherein "an actuating means positively compress and decompress the membrane" is considered as the third technical feature.

Since the above-mentioned groups of claims do not share any of the technical features identified, a "technical relationship" between the inventions, as defined in PCT Rule 13.2 does not exist. Accordingly, the international application does not relate to one invention or to a single inventive concept.