

[54] **PUMP APPARATUS FOR SLURRY AND OTHER VISCOUS LIQUIDS**

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[58] **Field of Search**.....**417/477, 476, 475, 474, 900; 418/45; 92/13.2**

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[57] **ABSTRACT**

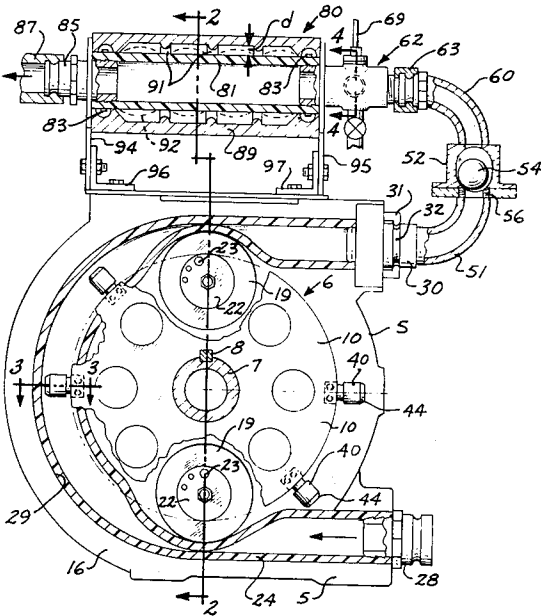
A peristaltic pump is operated by squeezing rollers pressing on an elastic tube supported inside a semicylindrical chamber. The collapsed tube is reopened by traveling side rollers which press the tube transversely. This expedites refilling and increases pump capacity. A surge chamber consisting of an elastic hollow cylinder housed inside a tubular housing provided with inwardly projecting annular ribs smooths out both minor and major surges in flow of the viscous material.

[56] **References Cited**

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6 Claims, 5 Drawing Figures



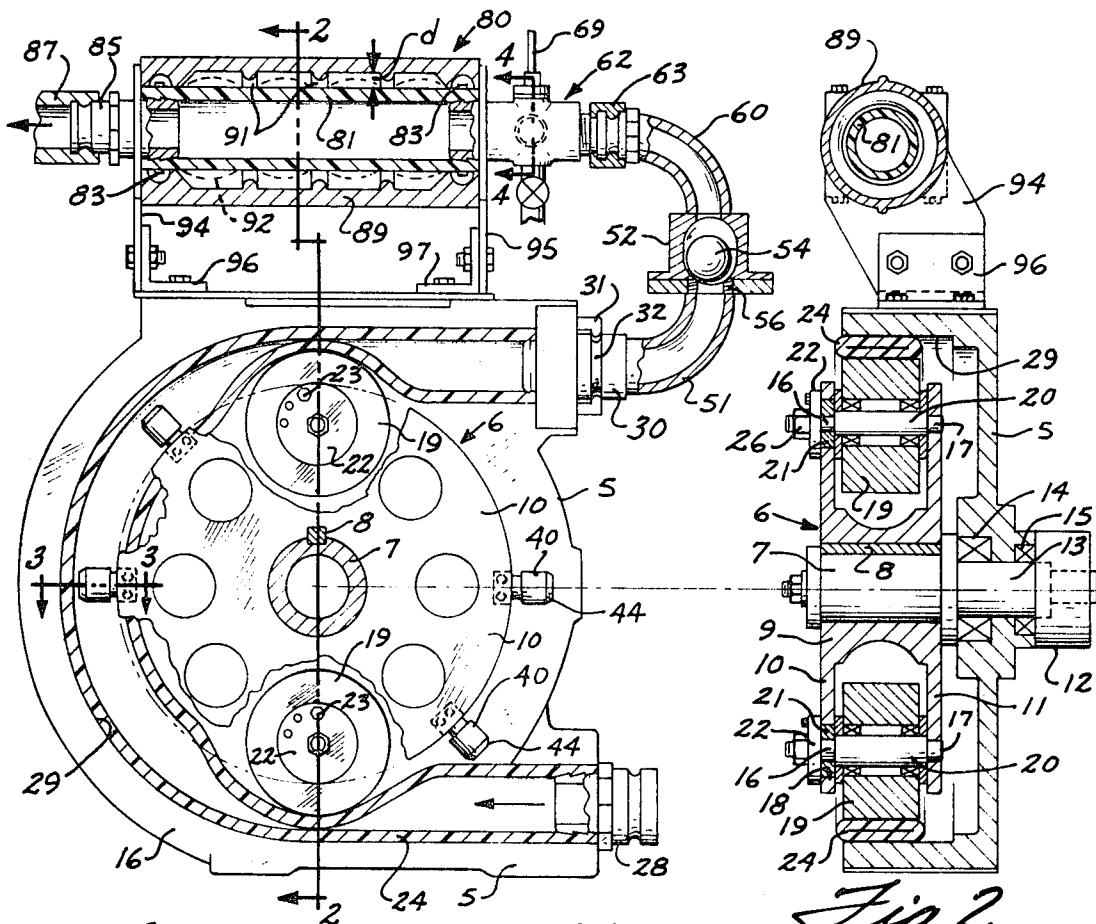


Fig. 1

Fig. 2

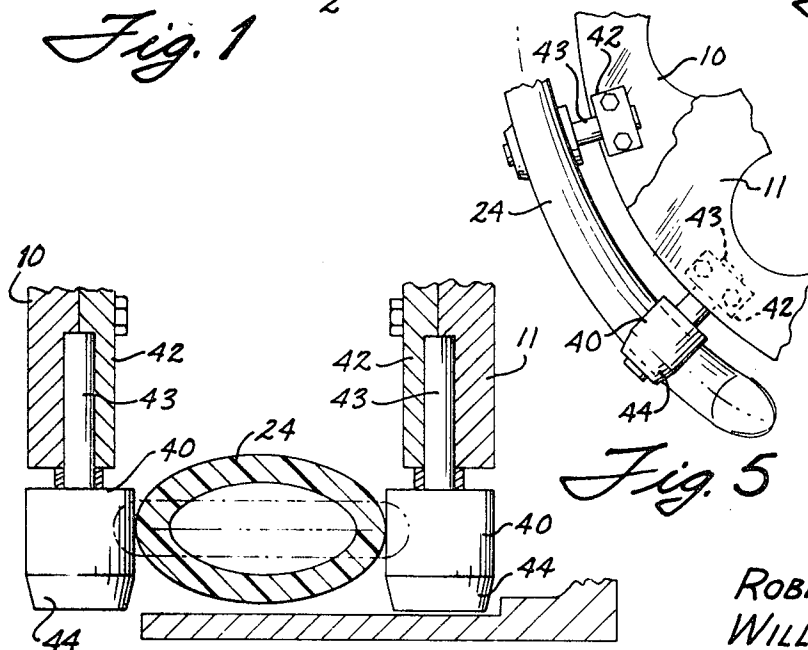


Fig. 3

Fig. 5

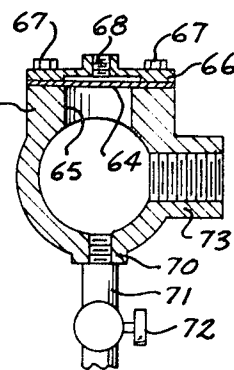


Fig. 4

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PUMP APPARATUS FOR SLURRY AND OTHER VISCOUS LIQUIDS

BACKGROUND AND PRIOR ART

Various devices have been proposed in the past for pumping viscous fluids such as explosive slurries. Such slurries are frequently very corrosive and abrasive to machinery and pumping operations involving them have presented serious problems in many instances because of their reactive solutions and also because of the nature of the suspended solids they contain. The pumping of blasting slurries is only one good example of the types of problems frequently encountered but analogous problems arise with other viscous liquids.

Slurry blasting agents commonly comprise a gelled liquid media in which solid particles of metal, such as aluminum, and/or carbonaceous materials such as ground gilsonite or coal, sugar, and the like, are suspended. These viscous materials are often quite heavily loaded with solid particles. In addition to metals and other fuel particles, granules of undissolved salts, such as ammonium nitrate, sodium nitrate, and the like, are frequently included in blasting slurries, although major proportions of these oxidizer salts usually are in solution. These salts are corrosive as well as abrasive.

Because of the abrasive character of the solid materials, the viscous, stringy and sometimes lumpy nature of the whole mixture, and the difficulty of handling them with more conventional equipment, there are advantages in using peristaltic pumps. These pumps are well known in principle, and are used for a variety of purposes. In pumping thick or viscous slurries, however, cavitation and other flow hindrance problems arise because of their slow flow properties. A peristaltic pump necessarily depends on successive squeezing and opening up of the collapsible tube or channel member to draw in a continuing supply of the material being pumped. With heavily loaded or viscous slurries, the rubber tubes or hoses which are used as tubes or channel members, often do not spring open rapidly enough to draw in the sluggish flowing material to be pumped so as to refill the tube. As a result, the pump operates inefficiently or discontinuously. At best, there tends to be a pulsating or intermittent type of flow.

An important aspect of the present invention is the provision of a more positive means by which the slurry may be drawn into the peristaltic tube. Rollers engaging the side edges of the flattened, emptied tube are used to open it up into a rounded, or approaching rounded, position so as to cause the tube to refill with slurry after the squeegee rollers have passed over it.

Even with peristaltic pumps, there are pressure surges, especially with the more viscous or heavily loaded slurries. These may be caused by variations in viscosity, solids loading, flow irregularities, etc. Pressure pulsations interfere with manipulations of the delivery hose, as when blasting slurry is being pumped into boreholes. In some cases they are severe enough to damage the pumping apparatus and even to burst the delivery hose. The latter, of course, can involve serious dangers to operating personnel and in any case it is essential that such pressure surges be minimized and eliminated as far as possible. The pumping apparatus often is associated with mixing equipment as is commonly mounted on a mobile vehicle, such as a truck or trailer where power equipment is available for driving the pump.

Surge chambers are known in the prior art, including elastic drums, tubes or cylinders which can yield and thus expand or contract to accommodate variations in flow velocity and pressure. Various types of pneumatic pressured surge chambers are known, also. However, it is most undesirable to have surges accumulate in substantial volumes. For example, when an operator is filling a borehole with explosive slurry, it is important for him to be able to start and stop the flow quickly, e.g. to avoid spillage or overflow. An expansive surge chamber, where a substantial volume of slurry can accumulate, makes close control more difficult. It is highly desirable to be able to smooth out low or high pressure surges without

accumulating relatively large masses of the viscous liquid in a surge chamber. An important object of the present invention is to be able to accomplish this.

While the surge chamber of the present invention is particularly suitable for the peristaltic pump, it is suitable also for use with reciprocating and other types of pumps where the pulse volume is not excessive. The surge chamber of the present invention is designed to accommodate small pressure surges with minimal volumetric expansion and to accommodate much larger surges in pressure with relatively little further volume expansion. This is accomplished by using an elastic tubular chamber member and surrounding it with spaced annular confining rings. Expansion of the tube, merely enough to bring its walls into contact with the rings, requires relatively small pressure increase. Further expansion, involving stretching of the tube walls between rings, or beyond rings, requires much larger pressure increments.

SUMMARY

This invention comprises a collapsible tube which forms a flow chamber for slurry or other viscous or heavily loaded or thickened liquids, positioned inside a cylindrical or part-cylindrical surface. Traveling squeeze or squeegee rollers, orbiting around a central axis which corresponds with the axis of the cylindrical surface, press the contents of the tube forward through a control chamber and into a surge chamber. From the surge chamber, the material may be delivered to a borehole or any other receptacle to be filled.

The collapsible tube, in the form of a rubber or other elastic member, tends to reopen after the squeegee rollers have passed over it. However, the viscous contents may tend to cause the inner walls to adhere to each other and the sluggish flow properties of the material being pumped tend to prevent rapid reopening of the tube. To overcome these tendencies, traveling rollers are provided to press on the edges of the flattened tube and assist it in reopening. This expedites considerably the flow of the viscous liquid into the tube, preparatory to the next flattening action of the main pressure or squeeze rollers.

The control chamber includes means for determining pressure applied to the material being pumped, means for releasing the material through a lateral vent when this is needed, and a "blow-down" connection, e.g., for admitting air or other fluid to remove material from the surge chamber and the delivery line or hose.

The surge chamber comprises an expandable tube of rubber or similar elastic material, preferably rather thick-walled, strong enough to contain high pressure but elastic enough to expand moderately at low pressure and more at high pressure. Surrounding this tube with an annular space between is a strong-walled chamber, provided with spaced inwardly projecting annular ring elements which almost contact the expandable tube, when in its normal relatively undilated condition. On expansion by a moderate pressure pulse, the tube dilates to contact the rings which largely prevent further expansion until a much stronger pressure surge forces the tube to stretch into narrow zones between or beyond the confining annular rings. Ribs of other shapes may replace rings.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a side view, with certain parts in section and certain parts removed, of a preferred embodiment of peristaltic pump, according to the present invention.

FIG. 2 is a transverse sectional view taken substantially along line 2—2 of FIG. 1.

FIG. 3 is an enlarged detailed view in section, taken substantially on line 3—3 of FIG. 1, showing the rollers which help to open up the peristaltic tube after its contents have been pressed out by the squeezing rollers.

FIG. 4 is a cross-sectional detail view through the control chamber, being taken substantially along the line 4—4 of FIG. 1.

FIG. 5 is a fragmentary view showing a side view of the opening rollers for the peristaltic tube.

DESCRIPTION OF PREFERRED EMBODIMENT

The pump per se consists of a more or less drum-shaped frame member 5 in which a rotating wheel member 6 is mounted on a hollow axle 7 to which it is keyed at 8. The wheel 6 comprises a hub element 9 and integral flange elements 10 and 11. The axle 7 is driven by an appropriate prime mover shown herein as a motor 12 secured to extension 13 of axle 7, mounted in antifriction bearings 14 and 15. A hydraulic motor is preferred for operating this particular unit in pumping slurry explosives because it offers less hazards than an electric motor. However, any appropriate prime mover can be used, e.g., electrical, gasoline driven, etc., depending on the circumstances and hazards involved.

Wheel 6 carries a pair of squeeze rollers 19 rotatably mounted on eccentric shafts 20 between the plate flanges 10 and 11. That is to say that the shafts 20 have reduced end portions 16 and 17 which are eccentric with respect to the main shafts 20. The ends 17 are mounted for free rotation in the right flange 11 but the left end 16 (as seen in FIG. 2) of each shaft passes through a bushing 21 concentric and coaxial with the ends 16 and 17, fitted into an enlarged opening 18 in left flange 10 of main wheel 6. A somewhat larger disc 22 is keyed or otherwise nonrotatably attached to end portion 16 so that either eccentric shaft 20 can be rotated to various positions by rotating disc 22. The latter can be fixed in the desired position by inserting a locking bolt 23 into the appropriate one of several holes in disc 22, being screwed into a threaded opening in the flange 10. By this means, the pressure of the squeeze or squeeze rollers 19 on the peristaltic tube 24 can be adjusted as desired. A nut 26 holds the shaft 20 tightly attached to disc 22.

The peristaltic tube 24 extends from an inlet connection 28 at the bottom of frame 5 along a horizontal course and then follows the interior of semicylindrical or drum surface 29 of member 5 to the top where it extends horizontally to the right to an outlet connection 30. Surface 29 is wide enough to support or back up the tube 24 when fully flattened by the rollers 19. Outlet connection 30 is firmly connected to tube 24 and is secured to frame member 5 by an arcuate locking flange 31 which fits into an annular groove 32 in coupling 30.

The tube 24 is a strong elastic hose or cylinder of rubber or similar deformable and elastic material, which may be suitably reinforced by fabric or other fibrous material, if desired. Its elastic properties tend to expand it to a normal round or near-round open condition after a squeezing roller has passed by.

The inlet end coupling element 28 preferably is of the quick-connect type, so that a hose or pipe connection from a supply tank or a mixing station can readily be attached or detached.

While tube 24 is or tends to be self-reopening, mechanical means are provided to help and accelerate such reopening after each passage of a squeeze roller 19. Clamped between bearing brackets 42 and the inner surfaces of flanges 10 and 11 are the shafts 43 on which edge pressing rollers 40 are mounted for free rotation. See FIG. 3, also FIG. 5. These rollers are arranged opposite each other in pairs and two pairs preferably are used to follow each of the main squeeze rollers 19, as shown in FIG. 1. While two squeeze rollers 19 are shown in FIG. 1, and this is the preferred arrangement, the pump will operate with only one, and three or more may be used, if desired. The side or tube opening rollers, of course, are used in such numbers and arrangements as required to open up the tube 24 after each squeezing operation.

The outer end of each roller 40 is beveled, or tapered, as indicated at 44, so as to engage the tube at a gradual angle and avoid damage to the tube. The second roller of each pair can be set inward, if desired, towards the tube 24 with respect to the first roller so that it further narrows the width of the tube which can be accommodated between the opposed rollers.

The rollers are so positioned radially with respect to the main axle 7 that they properly contact the edges of tube 24.

The structure so far described operates as follows: Slurry flows in through coupling 28 into the collapsible peristaltic tube 24. Assuming that this tube is open or opening, its expansion creates a partial vacuum which assists in drawing in the slurry or other liquid to be pumped from a source of slurry supply, not shown. It will be understood, of course, that the source of slurry supply sometimes may be under some hydrostatic pressure, which helps to cause the material to flow into the tube. Assuming first that the tube is full or substantially full of slurry, the rotation of wheel 6 around its central axis, as it is driven by shaft 7, rolls the squeeze rollers 9 around and against the inside of the peristaltic tube, pressing it against surface 29, FIG. 2, and squeezes the contents forward in clockwise direction, FIG. 1, through the outlet connection 30. The flattened tube thereafter is partially reopened by rollers 40.

From the pump, the slurry passes through outlet connection 30 through an elbow connection 51 and into a check-valve structure 52 which comprises a ball check valve 54 operating against a seat 56. This valve prevents back-flow of the slurry in case the pump is stopped, or in case of any other discontinuity in feeding slurry to the valve.

From check valve 52, another elbow connection 60 carries the slurry to control chamber structure 62 which has another quick connector 63 similar to connector 28.

As seen in cross section in FIG. 4, control chamber member 62 has a resilient diaphragm 64 across a top opening 65. Diaphragm 64 is clamped in place by a ring 66 held by bolts 67. A threaded opening 68 is provided for connecting a signal line 69 (see FIG. 1) which transmits a pressure reading from the diaphragm to an appropriate pressure gauge (not shown). By this means, the pressure on the slurry can be noted and/or recorded.

Member 62 also has a threaded drain or back-flow opening 70 through which the slurry or other liquid may be discharged or withdrawn through a suitable line 71 controlled by valve 72. This valve, normally, is closed. Through a side opening 73, also threaded, connection may be made to a pneumatic hose or other source of fluid pressure. By applying each pressure, the residual slurry or liquid in the outlet line and delivery hose, beyond check valve 54, may be blown out or discharged.

The upper part of FIGS. 1 and 2 show a surge chamber 80 which consists of an elastic tubular inner member 81 formed of gum rubber or other suitable strong elastic material, having not only a high tensile strength, but being stretchable to at least twice or three times its normal diameter without rupture. In a typical case, this tube 81 may be an elastic rubber tube having a wall thickness of one-eighth to one-fourth-inch or more and being 1½ to 3 inches or more in internal diameter. It may be made in various sizes for different purposes. A length of this tubular material 81 is connected by clamps 83 to the connecting outlet of chamber 62 mentioned above and to an outlet line 87 through a quick release connector 85. In normal operation of the pump already described, pumping of the viscous fluid material forces valve 54 open and the material flows through the other connection already described. Thus, the slurry or viscous liquid is pumped through the expandable conduit 81 and into its outlet line 87. Where this material is an explosive slurry, the line 87 may constitute or be connected to a long delivery hose whereby the slurry may be pumped into boreholes for blasting in large mining operations. As already noted, the pump can be used for other and analogous materials and is not limited to use with explosive or other slurries.

Surrounding the tubular conduit 81 but annularly spaced therefrom at a suitable distance *d*, is a rigid-walled tube 89. The latter may be a metal pipe, such as aluminum or steel of sufficient wall strength to withstand any pressure that can reasonably be expected from the pump. This surge chamber can be used also with other pumps or pressure sources connected to its inlet as already mentioned.

A plurality of ring members 91, preferably three as shown, are formed inside the rigid-walled conduit 89. They may be separate and held therein by friction or they may be integral with the wall member 89. These are preferably cast or formed with the rigid tube 89. However, they may be separate metal rings or other plastic material than rubber may be used. They are spaced in such a manner that some expansion of the tube 81 between them may be accommodated. When the tube 81 is not under substantial pressure, it preferably does not quite touch the rings 91, although it may be in light contact therewith, if desired. The spacing between the rings like their number depends on the magnitude of the pressure to which the tube 81 is to be subjected, on its material and wall thickness, and also on the material of which rings 91 are formed. In normal operation, it may be expected that the tube 81 would be expanded by a moderate pressure surge into contact with the inner annular surfaces of the rings 91. Expansion by much higher pressure is indicated by the dotted line 92, FIG. 1. The surge chamber is mounted on brackets 94, 95, bolted to the top of frame 5 through angle foot members 96, 97.

When a strong pressure surge is applied to the tube 81, it expands to contact the ring members 91. Between adjacent pairs of ring members it is expanded even further, bulging between the rings to an extent determined by the pressure and the elasticity and tensile strength or resilience of the tube material 81. For example, a surge pressure two to four times as great or even greater than that required to expand the tube to mere contact with rings 91 is required to expand the tube significantly into corrugations between the ring members 91, as shown at 92 in FIG. 1.

In a typical structure tested in accordance with this invention, a 2-inch gum rubber hose, having a wall one-fourth-inch thick, was first connected inside a 4-inch internal diameter metal pipe, which was otherwise unobstructed. The connections were substantially as shown in FIG. 1, with the pipe 89 spaced about 1 inch from the outer wall of the tube 81 when there was no pressure. Under normal operation and at moderate pressure, pumping slurry with a peristaltic type pump, the material flowed smoothly and the arrangement without rings 91 was satisfactory.

Another model was built using inside a 5-inch pipe a 2½-inch inside diameter gum rubber tubing with walls one-half inch thick in their normal, unexpanded condition. At 30 p.s.i. pressure at the end of a delivery hose, this tubing expanded to fill the casing which surrounded it. As pressure of 30 p.s.i. was exceeded, however, there was no further room for expansion and strong surging occurred in the delivery hose. This surging caused the hose to whip badly and might have burst a hose of moderate strength.

The system was first tested by pumping water, which is less compressible than slurry because slurry normally contains some aeration. The hose pressure on the liquid after passing through the surge chamber varied only about 2 p.s.i. in surges from an initial starting pressure of 0 up to about 30 p.s.i.g. pumping pressure. However as pumping pressure went higher, surges would suddenly jump to as high as 90 p.s.i., then dropping back to 30 p.s.i. This was repeated every half revolution of the peristaltic pump. The simple surge chamber thus described was therefore quite suitable as a surge absorber at working pressures up to 30 p.s.i. It was completely inadequate at pressures above 30 p.s.i.

On confining the tube just described with the series of spaced rings in the manner shown in FIG. 1, the rubber tubing was normally stretched out into contact with the rings but not greatly beyond them at a pumping pressure of 30 p.s.i. When stronger surges came along, the tube 11 was bulged or corrugated between the rings, as shown in dotted lines 92 but increments of pressure on the delivery hose were still very low, of the order of 2 or 3 pounds, as compared with as much as 60 pounds in the case described above.

When pumping water at 30 p.s.i. with the peristaltic pump and surge chamber of this invention, pressure would some-

times drop to 20 p.s.i., but not go appreciably above 30 p.s.i. When pumping at a nominal pressure of 80 p.s.i., the pressure normally did not drop below 60 p.s.i. during the low pressure cycle of the surge.

Table I shows typical results with water:

TABLE I

	Basic Pump	Pump + Ck valve	Pump + ck valve + Surge chamber	Pump + ck valve + surge ch. + Rings
P.S.I.G. (low)	30	30	30	30
Surge P.	-30(1)	-20(2)	-2(3)	-10(4)
P.S.I.G. (high)	90	90	90	90
Surge P.	-90(5)	-70	-60(6)	-20(7)

(1) Gauge needle struck stop peg.

(2) Good improvement — needle did not strike peg.

(3) Nearly constant — fine for low pressure pumping.

(4) Some fluctuations but not objectionable, considering pumping pressure.

(5) Gauge needle struck stop peg.

(6) Very large pressure fluctuation — destructive over a period of time.

(7) Big improvement over (6).

With reciprocating type pumps, pressure surges are expected to be somewhat greater. It is often desirable to use a somewhat larger expansion chamber of the type shown in FIG. 1.

With the structures shown, the pressure surge may be confined to desired low levels by adapting the size of the chamber to the volumetric magnitude of typical surges. It has been pointed out above that large volumetric expansion is undesirable. With a reciprocating pump, these surges, of course, are larger than in the case of peristaltic or other continuous flow devices. A reasonably steady flow at the end of the hose is desired, and it is desirable, also, to be able to cut off flow rather quickly without rupturing the tube 81 or the delivery hose, or doing damage to the pump.

As pointed out above, use of the confining rings around the rubber tube makes it possible to accommodate surges at operating pressures of two to four times or more those which are required merely to expand the tube into contact with the rings. The number of rings obviously may be varied with different diameters and lengths of tubing 81. While annular ribs or rings are preferred, such as shown at 91, it will be understood that ribs which will extend spirally, or axially may be used. Grids of riblike projections may be used in some cases. The annular ribs usually control the tube 81 better and place less strain on it.

The invention described above offers outstanding advantages in smooth, uniform flow. This is desirable and frequently is very important in delivering blasting slurry into boreholes. It is desirable, of course, to be able to control the flow with reasonable precision, and it is important to avoid whipping and other malfunctions associated with high pressure surges.

It will be obvious that modifications mentioned above and others not mentioned may be made by those skilled in the art without departing from the spirit and purpose of the invention. It is intended to cover the invention and obvious variations and modifications as broadly as the prior art permits.

What is claimed is:

1. A peristaltic pump apparatus for fluids such as slurries and the like which comprises, in combination, an arcuate channel in a frame member adapted to receive and house a peristaltic tube, a collapsible peristaltic tube fitted into said channel and having an inlet end connectable to a source of material to be pumped, a rotary carrier mounted concentrically with said channel, roller mounting means including an

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eccentric adjustable support secured to said carrier, a squeeze roller rotatably journaled on said mounting means for pressing and collapsing said peristaltic tube and thus forcing its contents forward from said inlet end towards an outlet, and plural successive pairs of tube opening rollers also carried by said rotary member and mounted progressively closer together to assist in opening the collapsed tube after the squeeze roller has passed along by pushing the edges of said collapsed tube towards each other in progressive steps thereby to accelerate refilling of said tube by said by said material from said inlet end.

2. Apparatus according to claim 1 which includes a plurality of squeeze rollers mounted on said rotary carrier and a plurality of pairs of said opening rollers following each squeeze roller.

3. Apparatus according to claim 1 which comprises an elastic surge chamber connected to the outlet of the peristaltic

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tube to smooth out the pump output.

4. Combination according to claim 1 which comprises a check valve connected to the pump outlet and a surge chamber connected to said check valve.

5. A pump according to claim 1 which includes a surge chamber of low volume expansion characteristics comprising an axially extending elastic inner chamber wall member, an outer chamber wall member coaxial with and spaced annularly from said inner chamber, and a plurality of spaced rib elements located in the annular space between said chambers and adapted to limit expansion of the elastic inner chamber wall member.

6. A pump according to claim 5 wherein the spaced rib elements are in the form of spaced annular ring elements protruding inwardly from the outer chamber wall member.

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