

[54] PUMP

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[56]

References Cited

UNITED STATES PATENTS

2,321,828	6/1943	Lane	417/415
3,556,679	1/1971	Middlebush	417/415
3,818,805	6/1974	Johansson	92/87

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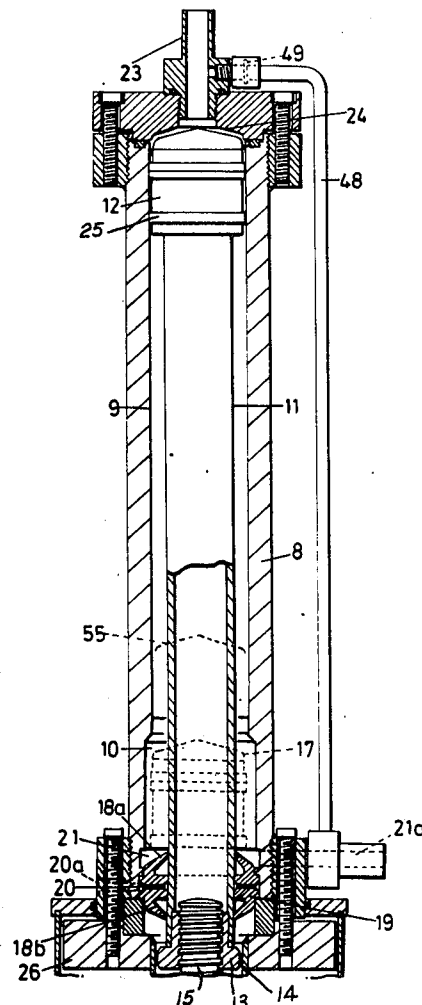
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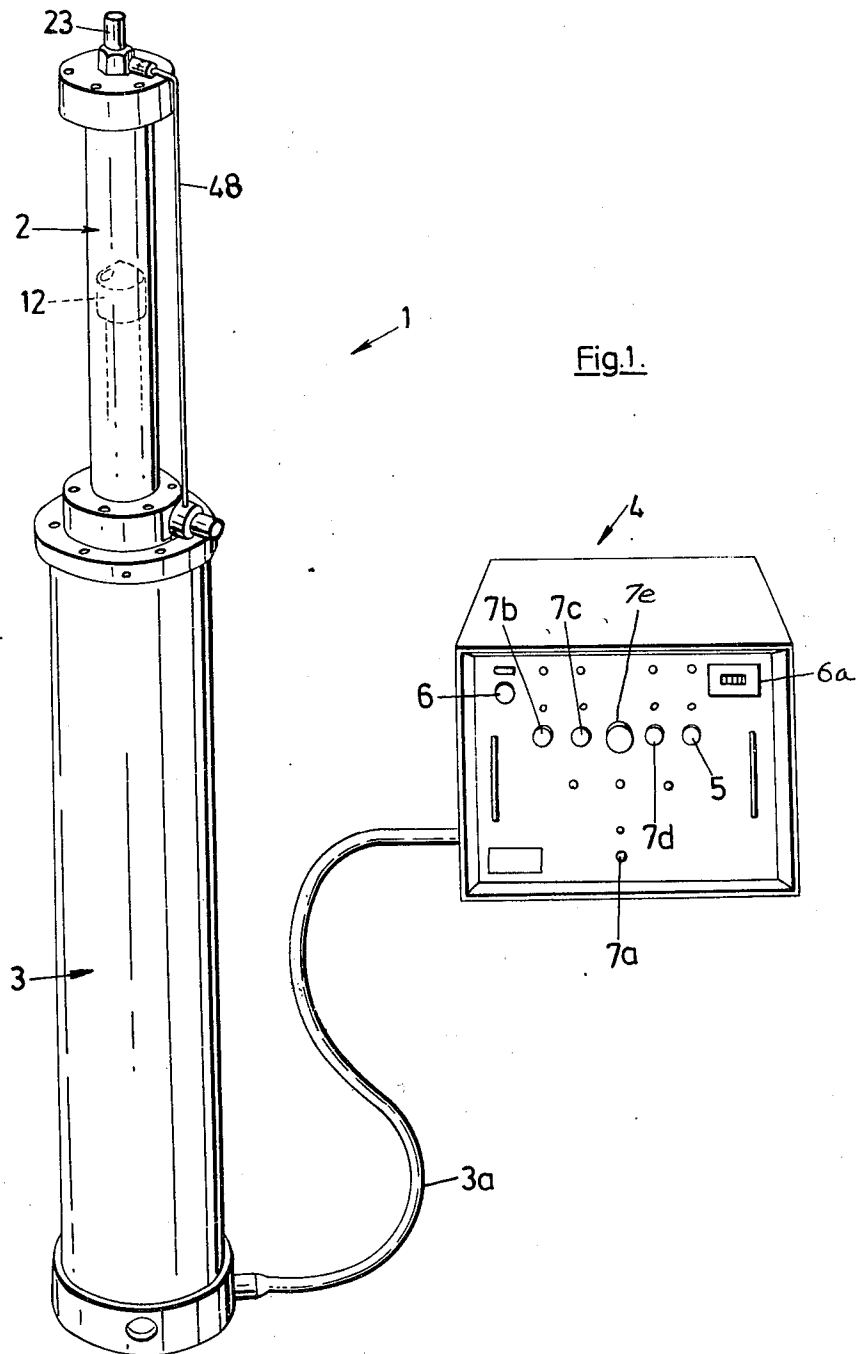
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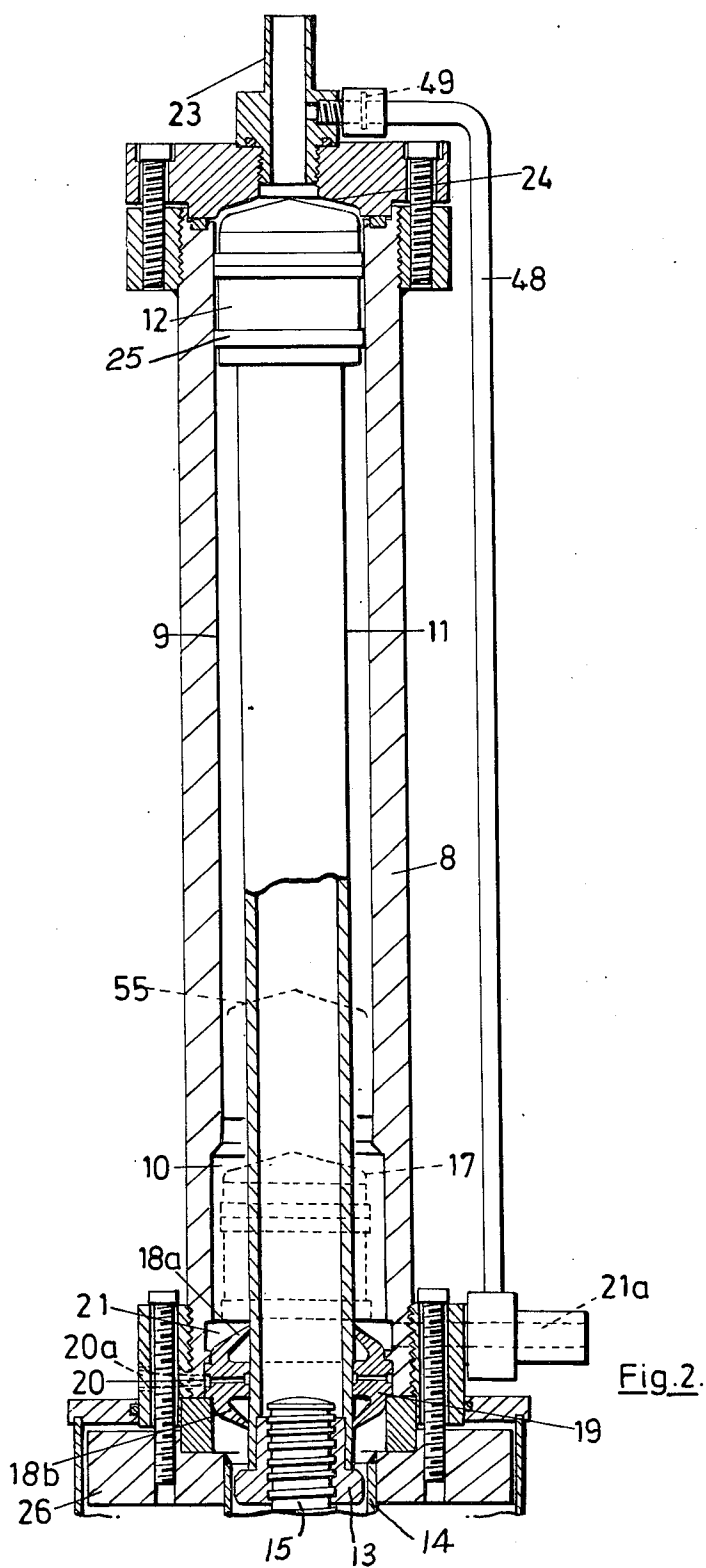
ABSTRACT

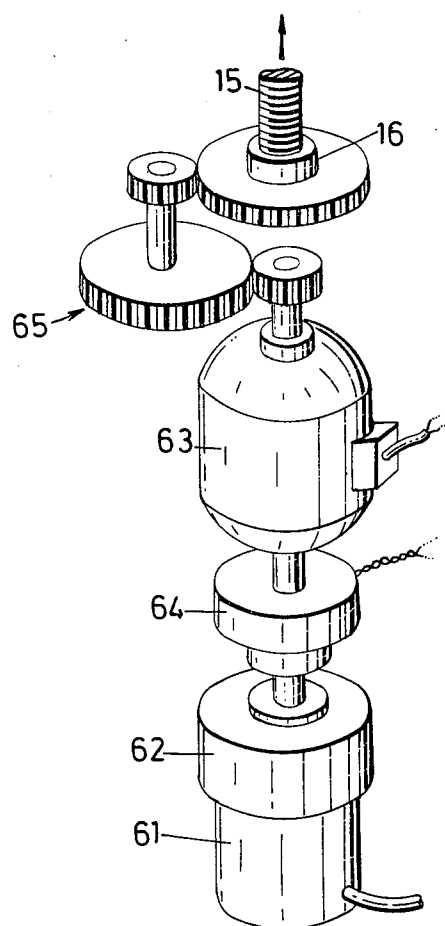
An automatic chromatography pump having a stepped bore with a narrow pumping portion and a wide cleaning portion allowing complete draining and flushing of the pump. Two motors are provided, one for low speed continuous stroke pumping operations and another for high speed strokes for pumping and cleaning purposes.

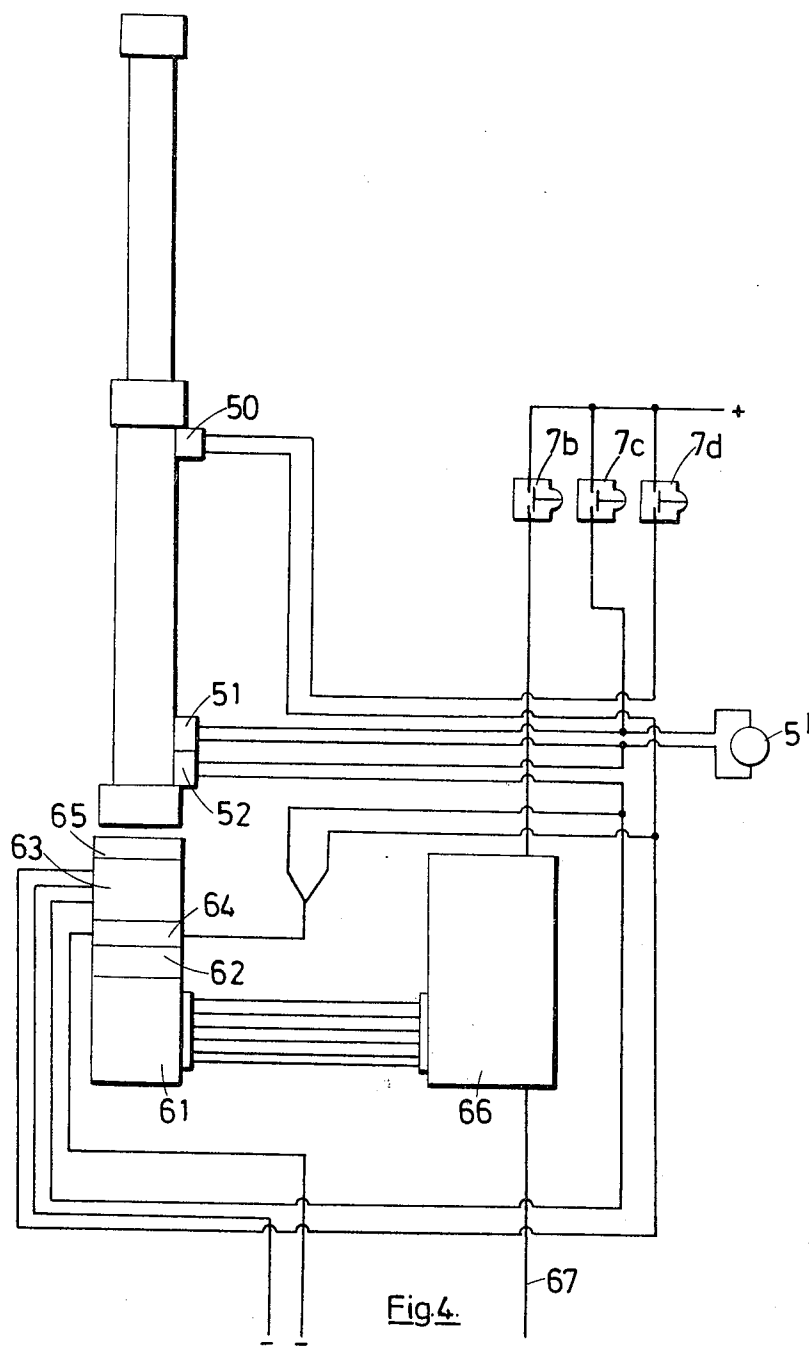
6 Claims, 4 Drawing Figures







Fig. 3.



PUMP

The present invention relates to a pump, and one preferred form of the present invention provides a pump which is particularly suitable for chromatography analysis.

In operations such as chromatography analysis when it is desired to use a single pump to urge several different constituents successively through the apparatus it is traditionally difficult to clean the pump of each particular material before use in the next successive pumping operation.

According to the present invention we provide a piston pump in which the cylinder bore is vertical and has two portions of distinctly different diameters, the piston being dimensioned to conform closely with the smaller diameter portion in the upper part of the bore for sealing-tight pumping operation therewithin, and means being provided for optionally withdrawing the piston down into the larger diameter portion at the lower end of the bore for cleaning purposes and for guiding the piston coaxially of the larger bore portion.

Preferably, the pump includes means normally preventing withdrawal of the piston from the smaller diameter bore portion but operable to allow withdrawal of the piston into the larger diameter bore portion upon operation of an override control. More preferably, the means for preventing withdrawal of the piston from the smaller diameter bore portion may comprise a limit switch which is actuated to prevent further movement of the piston in a withdrawal direction once the piston arrives at one end of the smaller diameter bore portion. A further limit switch may suitably be incorporated to stop movement of the piston once the first mentioned limit switch has been overridden to allow the piston to be withdrawn into the larger diameter bore portion.

Conveniently the piston head and the upper end of the cylinder may be of conical configuration and conform closely to one another so that, in the uppermost position of the piston, a small working space remains between the conical piston head and the conical end wall of the cylinder.

Desirably the lower end of the chamber may be so constructed that, when the piston is withdrawn into its lowermost position in the larger diameter bore portion, any liquid in the larger diameter bore portion can drain away through a suitably positioned drain outlet. The pump may particularly desirably include means for driving the piston slowly from one end position of the smaller diameter bore portion of the cylinder to the other end of the smaller diameter bore portion in one continuous stroke in a pumping operation, and means for preventing further movement of the piston upon arrival at said other end.

Suitably the slow driving means may comprise a first motor for driving the pump piston in a continuous stroke along the cylinder, and a further motor may be provided operable at a higher speed than the first motor, means being incorporated for terminating drive of said further motor and for simultaneously engaging the first motor as the piston reaches a predetermined position at the end of a high speed drive phase.

Preferably the first motor is a stepping motor connected to a reduction gearbox, said further motor is connected to the output of said gearbox by way of a clutch, and the further motor is connected to the drive of a screw jack of the piston and cylinder pump, more

preferably by way of a further reduction gearbox. With this arrangement the high speed motor is driven by the stepping motor and gearbox in slow speed operation and the clutch is releasable to disengage said stepping motor and gearbox during high speed operation but engageable to brake the pump at the end of a high speed phase.

In order that the present invention may more readily be understood, the following description is given, merely by way of example, reference being made to the accompanying drawings, in which:

FIG. 1 is a perspective view showing a chromatography pump constructed in accordance with the present invention together with its control unit;

FIG. 2 is a side elevational view, partly in section, showing the pump mechanism of the pump of FIG. 1;

FIG. 3 is a schematic perspective view of the drive train to the pump lead screw; and

FIG. 4 is a partial circuit diagram for the pump drive and control systems.

The chromatography pump 1 of FIG. 1 includes a pump unit generally designated 2 extending vertically upwardly from the top of the drive casing 3. The drive casing encloses a stepping motor for normal pumping operation and a high speed motor for purging as will be seen with reference to the later description of FIG. 3.

A control unit generally indicated 4 is connected to the drive casing by a loom 3a of electrical conductors to supply the two motors and to communicate with the various limit switches and the clutch control within the drive casing 3.

The controls on the unit 4 include an override button 5 which can be operated to allow the piston 12 of the pump to be withdrawn into a larger diameter lower section of the cylinder for the purposes of draining and cleaning the pump. A limit switch which normally prevents the piston from leaving the upper, narrow diameter pumping bore portion is rendered inoperative when the override button is pressed.

A variable speed control 6 enables the speed of the stepping motor to be adjusted and a digital indicator 6a is provided to give a readout proportional to the pump speed. The control 6 is operative when a push button 7b has been depressed to energise the stepping motor windings.

An on-off switch 7a controls the supply of power to the control unit and must be switched on before any of the pump facilities can be used. A push button control 7c can be depressed to trigger rapid movement of the piston upwardly along the bore of the cylinder under the power of the fast drive motor and to disengage the clutch 64 to isolate the stepping motor from the rest of the system. A further push button 7d can be depressed to trigger movement of the piston downwardly in the return direction. Finally, the push button in the centre of the panel referenced 7e can be operated to stop the pump at any time during its operation.

The time taken for a single stroke of the piston in the "fast drive" configuration is of the order of from 30 to 40 seconds depending on whether the piston descends into the larger diameter bore portion. The longest time taken for a single stroke in the main drive position is 250 hours.

As shown in FIG. 2, the pumping unit 2 consists of a cylinder 8 having a main, smaller diameter bore portion 9 at its upper end and a separate larger diameter bore portion 10 at its lower end for pump cleaning purposes. The piston consists of a tube 11 having at its upper end

the piston head 12 which slides within the smaller diameter bore portion 9 as a tight sealing fit. At the lower end of the tube 11 is a square sectioned nut 13 which slides within a square-sectioned housing 14 and is prevented from rotation relative thereto. Extending up the centre of the tube 11, and threaded through the nut 13, is a lead screw 15 for rotation by a drive shaft (not shown) fixed at its lower end. Clearly therefore, as the lead screw is rotated in one direction the nut 13 and the piston sleeve 11 and head 12 will move upwardly along the pump cylinder bore 9, 10. Rotation of the lead screw in the opposite sense will effect retraction of the piston.

At the end of each pumping cycle, which as indicated above consists of a continuous slow moving stroke of the piston in an upwardly direction along the cylinder bore portion 9, it is sometimes desirable to flush out the pump to eliminate all trace of the material which has just been pumped in order to prepare for a different composition to be pumped. In certain traditional metering pumps used for chromatography this operation can take of the order of 30 minutes because of the need to dismantle the pump completely in order to clean the entire working area of the pump. However, in the presently proposed pump it is possible for the piston head 12 to be retracted to its broken line position 17 in order that it lies entirely within the larger diameter flushing bore portion 10 where ample clearance is provided between the piston head 12 and the walls of the wide bore portion 10 to provide for flushing of the pump. Liquid may be introduced into the pump cylinder by the fast-drive return control, or alternatively the pump control unit may be given a slow speed return capability for this purpose.

Liquid is prevented from entering the drive casing from the cylinder portion 9, 10 by means of an elastomeric or other plastics sealing ring in this case of polytetrafluoroethylene.

The particular sealing ring illustrated, consists of upper and lower wiping portions 18a and 18b, respectively of cup form, and a central bearing portion 19 in which a drain groove and passage system 20 is arranged in order to allow radially outward removal of any liquid which passes the wiping portions 18a and 18b. This drain groove 20 is connected to a secondary drain passage 20a.

Clearly, once the piston head 12 has been withdrawn to its broken line position 17 in the flushing bore any residual liquid in the small diameter cylinder portion 9 and in the large diameter cylinder portion 10 will drain away completely due to the upwardly convex surface of the upper wiping portion 18a of the sealing ring 18 sloping continuously down towards an annular drain channel 21 connected to a main drain outlet 21a.

When the piston is in its flushing position 17 it is a simple operation for the pump working chamber to be flushed out by feeding a suitable medium in through the main pumping outlet 23 at the top of the cylinder whereupon the pump can be actuated for one cycle in the fast drive mode with the result that the piston can traverse upwardly along the length of the cylinder to its top position illustrated in FIG. 2 and then may return to the lower position 17 all within an interval of the order of 60 to 80 seconds.

The flushing operation may be repeated if it is considered necessary.

In order to avoid the possibility of air becoming trapped in the working chamber of the cylinder, the

upper end wall 24 of the cylinder is of conical form with the pumping outlet port 23 at the apex. The piston head 12 has a similar conical end wall conforming with that of the cylinder.

As shown in FIG. 2, a return line 48 teed off from the main delivery line 23 includes a bursting disc 49 which will normally resist access of the delivery liquid to the return line 48. However, once the delivery pressure reaches a predetermined maximum, the disc 49 will burst allowing the delivery fluid to escape down the line 48 into the main drain passage 21a to relieve the delivery pressure and avoid damaging associated apparatus.

The piston head 12 is provided with suitable sealing rings 25 and is thus able to pump under high working pressures with a positive displacement action and precisely constant delivery rate.

The vertical mounting of the cylinder is considered an important feature of the present pump since this enables any air trapped in the cylinder to rise to the conical top end wall of the cylinder to be bled off before the actual pumping stroke starts. Furthermore, by mounting the cylinder in a vertical configuration it is ensured that the best possible draining action of residual liquid in the pumping chamber can take place when the piston head has been withdrawn to its broken line flushing position 17.

The drive shaft 16, FIG. 3 at the lower end of the lead screw 15 is supported by a thrust ball bearing (not shown) to absorb the axial loads resulting from pumping at a high delivery pressure.

As shown in FIG. 3, the drive train to the lead screw 15 consists of a slow speed motor in this case a stepping motor 61 driving, by way of a secondary gear box 62 and an electromagnetic clutch 64, a high speed motor 63. The drive connection to the lead screw is by way of a primary reduction gear box 65 common to both main drive and high speed drive and disposed between the high speed motor 63 and the drive shaft (not shown).

Control of the position of the piston head 12 longitudinally of the cylinder 8 is effected by means of three double pole limit switches 50, 51 and 52 shown in FIG. 4. Limit switch 51 controls the conductor providing power supply to the high speed motor to stop the motor when the piston head 12 is in its broken line position 55 (FIG. 2) at the bottom of the pumping bore portion 9. The upper switch 50 serves to interrupt the power supply to both motors when the piston head 12 reaches the top of its stroke, and the lowest limit switch 52 shuts off power to the high speed motor in the flushing position 17 of the piston.

In the broken line position 55, the piston head is still sealingly engaged in the smaller diameter pumping bore portion 9 but descent below this position would signify exposure of the piston sealing rings to a shallowly tapered bore portion between the narrow bore portion 9 and the wide bore portion 10 which would begin to break down the sealing effect of the piston rings. Thus the limit switch 51 defines the lower extreme position of the piston in the pumping bore portion 9, but can be overruled using the override button 5 (FIGS. 1 and 4) to enable the piston to descend below the broken line position 55 to the flushing position 17.

A particularly convenient aspect of the presently proposed pump is that the cylinder 8 is bolted to a centre member 26 which also supports the lead screw housing 14 to the bottom end of which the main thrust bearing (not shown) of the lead screw is also secured and thus

the entire unit consisting of the lead screw 15, the piston tube 11, piston head 12, cylinder 8 and lower housing 14 forms a single sub-assembly within which all the axial loads are absorbed by virtue of the main thrust bearing (not shown). Thus no axial loading whatsoever is taken by the motors, clutch and gear boxes.

Using the chromatography pump of the present invention it is possible to carry out chromatography operations with extreme ease by virtue of the fully automatic control provided by the limit switches and furthermore it is a simple matter to withdraw the piston head 12 to its flushing position to allow the residual liquid at the end of the pumping operation to drain from the pump and to facilitate flushing of the pump before the next chromatography operation.

After flushing, it is merely necessary to allow the flushing solvent to drain from the pump and then to actuate the fast drive motor 63 to raise the piston rapidly to the position illustrated in FIG. 2, so that the main outlet 23 can then be connected to a source of fresh material. This material can be entrained into the cylinder 8 upon actuation of the fast drive motor 63 to withdraw the piston down along the narrow cylinder bore portion 9. Once the piston head reaches its broken line starting position 55 the stepping motor 61 can be selected using the push button 7b to initiate the controlled continuous pumping stroke required.

FIGS. 3 and 4 illustrate schematically the drive system to the pump unit 1.

The stepping motor 61 drives the lead screw drive shaft 16 through a 15:1 stepdown gearbox 62 and a high speed motor 63 which can be electrically de-energised to allow unobstructed operation of the stepping motor 61. The preferred form of stepping motor 61 employed is one which will operate from speeds of $\frac{3}{4}$ r.p.m. to 150 r.p.m. The total travel of the screw jack is 250 mm and the pitch of the screw is approximately 5 mm.

This combination of stepping motor 61 and gearbox 62 will provide a total time for a full stroke of the pump variable between a minimum of 75 minutes and a maximum of 250 hours.

The stepping motor drive unit 66 is connected to the variable speed selector control 6 of FIG. 1 to ensure that the frequency of the drive pulses to the stepping motor can be varied at will to vary the speed of the operation of the motor 61.

However, during normal operation of the high speed motor 63 the stepping motor 61 is disengaged as the clutch 64 is de-energised to isolate the stepping motor 61 and gear box 62 from the high speed motor 63, gearbox 65 and pump lead screw.

The normally open switch 5' operated by the push button 5 of FIG. 1 can be seen in FIG. 4 as bridging the lower limit switch 51. When the override push button 5 is operated to close switch 5' the circuit reacts as though the switch 51 were closed so the high speed motor 63 will resume operation to lower the piston still further provided the push button 7d has also been depressed. Once the lowest limit switch 52 is opened, the supply to both the high speed motor 63 and the clutch 64 is interrupted thereby causing immediate braking of the piston as the drive shaft 16 and the now de-energised high speed motor 63 are drivingly connected to the stationary de-energised stepping motor 61 to stop the piston in its flushing position.

One preferred form of stepping motor for use with the drive system of the present invention is a Sigma

motor and a USD 853 stepping drive unit manufactured by Unimatic Engineers Limited.

Starting from a configuration in which the piston is at the top of its stroke, the pump has been cleaned ready for use, and the mains supply conductor is energised, the push button 7d is depressed to withdraw the piston rapidly downwardly thereby inducing entry of liquid to be pumped in through the inlet 23 at the top of the cylinder 2 from a suitable liquid source (not shown). The piston will continue to descend until either limit switch 51 (FIG. 4) trips to arrest the fast descent of the piston, or the piston is otherwise arrested by operation of the manual control 7e.

At this stage, the pump cylinder 2 is connected up to a chromatography apparatus by way of the inlet/outlet line 23 either by physically disconnecting the line 23 from the liquid source and then reconnecting to a chromatography apparatus or, more preferably, by operating a three-way valve already connected to (a) the line 23, (b) the liquid source and (c) the chromatography apparatus, to isolate the liquid source from the pump and connect the pump to the chromatography apparatus.

With the bore connected to the chromatography apparatus the feed control 6 is rotated to select an appropriate, slow piston speed indicated on the digital counter 6a. Then the push button 7b is depressed to energise the windings of the stepping motor 61 for initiating slow ascent of the piston up through the pumping bore 9 of the cylinder 2.

If desired at any time during ascent of the piston, the "stop" push button 7e may be depressed to arrest ascent prematurely. Otherwise, the piston will continue to rise until the limit switch 50 (FIG. 4) is tripped to arrest the piston automatically as it arrives at the head of the cylinder. This completes a discharge or delivery stroke of the pump.

The cycle may be repeated with similar or quite different volumes of the same liquid, but if a different liquid is to be introduced it is necessary to follow a procedure intended to clean the pump ready for use with the next liquid.

Preparation for the descent operation involves disconnecting the inlet/outlet line 23 from the chromatography apparatus and either venting or reconnecting the source of the previous liquid. Then the "fast return" push button 7d is depressed to draw the piston downwardly, an operation lasting of the order of 30 to 40 seconds as indicated above.

The piston is allowed to descend to the bottom of the narrow diameter pumping bore portion 9 until arrested by the tripping of microswitch 51. Then if cleaning is desired the override button 5 is depressed with button 7d to command descent of the piston into the cleaning bore portion 10. Otherwise the piston will be held at the bottom of the pumping bore portion 9 until the next ascent, pumping stroke is desired.

When, for a cleaning operation, the piston arrives at the draining position in the larger diameter cleaning bore portion the microswitch 52 is tripped to stop the piston and the pump is now ready for cleaning.

Alternatively, during descent before cleaning, the override button 5 may be pressed simultaneously with the fast down button 7d during descent of the piston in the pumping bore portion 9 so that the piston will continue its descent through the position in which the microswitch 51 is operated and will only stop upon arrival at the draining position in the bore 10 where micro-

switch 52 operates.

Depending on the nature of the liquid being pumped, the pump can either be allowed to stand to drain any remaining liquid from the walls of the narrow diameter pumping bore portion 9 and from the head and skirt of the piston 12 into the annular well 21 around the upper seal portion 18a to be allowed to drain through passage 21a, or alternatively the pump may be flushed out by means of a suitable purging or flushing liquid admitted through the inlet/outlet line 23.

Once the draining and/or flushing operation has been completed the push button 7c is pressed to initiate rapid ascent of the piston to its starting position at the top of the narrow diameter pumping bore portion 9 ready for induction of the next liquid to be pumped.

We claim:

1. A metering piston pump including a vertical cylinder having a smaller diameter bore portion and a greater diameter bore portion at the lower end of said smaller diameter bore portion, a piston rod extending coaxially through the cylinder, a piston disposed at the upper end of said piston rod and dimensioned to conform closely with said smaller diameter portion of the bore for sealing-tight pumping operation therewithin, means for driving said piston upwardly and downwardly along said narrow diameter bore portion, means for optionally withdrawing the piston down into said larger diameter bore portion and for guiding the piston coaxially of the larger diameter bore portion, drain means communicating with the bottom of said wider diameter bore portion, and seal means in the lower end of said cylinder and surrounding said piston rod for guiding liquid draining into said larger diameter bore portion from the piston and the smaller diameter bore portion to drain away through said drain means when the piston is withdrawn entirely into the larger diameter bore portion.

2. A pump as set forth in claim 1, and further including second means normally preventing withdrawal of the piston from said smaller diameter bore portion into said larger diameter bore portion, and override control means for operating said second means to allow withdrawal of the piston into the larger diameter bore portion.

3. A pump as set forth in claim 2, wherein said second means comprise limit switch means actuatable to prevent further movement of the piston in a withdrawal direction once the piston arrives at one end of the smaller diameter bore portion.

4. A pump as set forth in claim 3, and including further limit switch means effective to stop movement of the piston once the first mentioned limit switch means have been overridden by said override control means to allow the piston to be withdrawn into the larger diameter bore portion.

5. A pump as set forth in claim 1, wherein said piston has a piston head of conical configuration; and the cylinder has an upper end also of conical configuration said conical piston head and cylinder end being shaped to conform closely to one another to define, in the uppermost position of the piston, a small working space between the conical piston head and the conical end wall of the cylinder.

6. A pump as set forth in claim 1, wherein said piston has a first predetermined position in said larger diameter bore portion fully withdrawn from said smaller diameter bore portion, a second predetermined position within that end of said smaller diameter bore portion adjacent the larger diameter bore portion, and a third predetermined position at the other end of the smaller diameter bore portion, and further including first electric motor means for driving said piston in a continuous stroke along the cylinder between said second and third predetermined positions, further electric motor means operable at a higher speed range than the first electric motor means for driving said piston between said first and third positions, means for interrupting driving engagement of said first electric motor means and said piston when said further electric motor means is electrically energized, and means responsive to arrival of said piston at said second predetermined position when being driven by said further electric motor means towards said first predetermined position for electrically de-energizing said further electric motor means and for simultaneously effecting driving engagement between said first and second electric motor means.

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