(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 126 170 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
22.08.2001 Bulletin 2001/34

(51) Int Cl.[7]: **F04B 33/00**, F04B 39/00, F04B 39/12

(21) Application number: **00301134.3**

(22) Date of filing: **15.02.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

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(54) Pump with tapered bore

(57) A gas or vapour pump comprising a compressible piston slideably accommodated in a bore in a housing wherein the cross sectional area of the bore and the piston decreases towards an outlet of the pump. The decrease in bore produces a reduction in the force required to move the piston.

Figure 1

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Description

[0001] The invention relates to pumps for gases or vapours which are either manually operated or mechanically driven. A particular example of a manually operated pump is a bicycle pump.

[0002] Pumps for gases or vapours are well known in a wide variety of applications. In essence they comprise a cylindrical housing which accommodates a piston. The piston is in sealing arrangement with the internal surface of the cylinder. Progression of the piston from one end of the cylinder to the other compresses the gas or vapour ahead of the piston until, when a certain pressure is reached, the gas or vapour exits through an outlet of the pump, into the desired receptacle such as the bicycle tyre. As the pressure on the other side of the outlet increases, the force required to move the piston increases.

[0003] This is evident when using a bicycle pump as the effort required to operate the pump increases significantly as the desired tyre pressure level is reached.

[0004] When the pump is a component of a mechanical device, and the piston is driven mechanically, for example, in engines or heavy machinery, the implications on the design of the machine are significant. The force applied and therefore the strength of the drive mechanism as a whole must be sufficient to provide and withstand the maximum force required in order to move the piston.

[0005] Liquid delivery pumps having a rigid plastics body with a tapered internal bore are described in British Patent Application No. 2070731. In this case however, the taper is intended to assist in the moulding process used to produce the pump and is kept to a minimum.

[0006] British Patent No. 1452867 describes a fluid translating device which is intended to be operated at high temperatures. The bore of the cylinder in that case is modified progressively along the length of the housing so as to compensate for the distortions in the housing or the piston at the high pressures encountered. Thus in use, the cross section of the cylinder remains constant throughout its length.

[0007] US Patent No. 4,997,420 describes drug delivery devices which operate automatically under the influence of a spring. The bore of the device is tapered outwards towards the outlet end in order to reduce the friction of the piston against the side walls of the device to compensate for the reducing force exerted by the spring.

[0008] None of the pumps addresses the problem of the level of force required to move the piston.

[0009] According to the present invention there is provided a gas or vapour pump comprising a compressible piston slidably accommodated in a bore in a housing wherein the cross sectional area of the bore and the piston decreases towards an outlet of the pump.

[0010] The force needed to move the piston is directly proportional not only to the pressure to be overcome, but also the area on which the pressure is acting. By reducing the area on which the piston has to work, the force required will decrease as the piston will be better able to overcome the pressure.

[0011] Suitably, the decrease in cross sectional area of the bore and piston is such that it reduces the force required to move the piston as compared to a cylindrical pump of similar volume and length by a significant amount, for example by at least 30%, and preferably at least 50%.

[0012] The ratio of the cross sectional area of the bore at the outlet region of the housing to the cross sectional area at the opposed end of the housing would suitably be in the range of from 1:1.2 - 1:25, preferably from 1:2.5 - 1:5 and most preferably from about 1:3. For example, where the bore is circular in cross section, the ratio of the diameter of the bore at the outlet to the diameter at the opposed end of the housing is in the range of from 1:1.1 to 1:5, preferably from 1:1.5 to 1:3.

[0013] However, the bore and similarly the housing may be variously shaped in cross section including polygonal shapes such as square, triangular, hexagonal or octagonal.

[0014] Suitably the bore of the housing is tapered downwards towards the outlet, thus forming a substantially frustro-cone shape where the bore has a circular cross section throughout its length. However, other shapes such as curved or profiled surfaces may also be used.

[0015] The housing may be made of metal such as steel or aluminium, or plastics depending upon the purpose for which the pump is to be used.

[0016] The compressible piston comprises a deformable structure, suitably of an elastomer or rubber material. The elastomer may be a synthetic impermeable foam such as polyurethane, neoprene or EPDM. A particularly preferred material is sold under the trade name Dynathane™, available from Hyperblast, Birch Vale, Stockport UK, or from Polyurethane Products Limited (PPL), UK. Materials with such properties and which may be compressed to the necessary degree to allow operation of the pump of the invention are known, or may be produced using conventional methods in the materials science art.

[0017] The piston may be shaped so as to facilitate compression. A particularly preferred shape is a cup shape where the rim of the cup is in sealing contact with the bore. Suitably the piston rod is attached at the base of the cup so that the rim of the cup progresses foremost through the bore.

[0018] In a further embodiment, the piston may be provided with an annular compressible washer arranged to contact

the internal surface of the housing and to deform as the piston progresses through the bore, allowing it to remain in sealing contact with the surface of the bore throughout the piston stoke.

[0019] Other deformable structures which may be used as the piston, include fluid filled sacs which contain sufficient fluid to ensure that the piston remains in sealing contact at the widest point of the bore, but which can elongate during the piston stroke.

[0020] In a preferred embodiment, means are provided in order to ensure that the piston remains axially centred within the housing throughout its stroke. These means may take the form of a guide arranged behind the piston on the piston rod. Suitable guides will have at least two semi-rigid elements, for example of a plastics or metal material, attached to or mounted on the piston rod such that they project outwards to the internal surface of the bore. The elements are of equal length and are suitably inclined so that they project away from the outlet of the housing. They will be rotatable about the end which is adjacent the piston rod to allow them to be deflected as the piston rod moves along the housing so as to accommodate the decreasing cross sectional area of the bore. The deflection of each element will be similar and so the rod will be held in a central position throughout the stroke.

[0021] Preferably at least four such elements and preferably up to 8 elements will be provided. These are suitably spaced equidistantly around the piston rod.

[0022] Alternatively or additionally, the housing may be provided with a rigid sleeve, in the region where the piston rod enters the housing. The sleeve may project inwardly or outwardly of the housing, preferably inwardly, and is arranged to slideably accommodate the piston rod along a portion of its length so that it maintains an axial path through the housing.

[0023] The invention is particularly suitable for use in gas pumps such as manually operated bicycle pumps although other gas or vapour pumps as are understood in the art, can utilise the invention. In particular the invention may be used for pumps which are driven mechanically as are found in engines or industrial machinery.

[0024] The degree of the reduction in the force achievable using the pump of the invention as compared to a cylindrical pump depends upon the reduction in the cross sectional area and the other dimensions of the pump. It may be calculated mathematically.

[0025] For example, the cylinder of a typical bicycle pump is 35cm in stroke and the volume of gas or vapour which is moved during a piston stroke is of the order of 110cc. The expected reductions in force required as compared to a conventional cylindrical pump can be calculated as a function of the final cross sectional area. These are set out in Table 1.

Table 1

Ratio of initial piston area to final piston area	Final piston force as fraction of parall el bore pump of radius =1	Final area of piston (sq cm)	Final radius of piston (cm)	Initial area of piston (cm)	Initial radius of piston (cm)	Semi-angle of taper (deg)	Fig	Ratio of initial to final diameters
1	1	3.142	1	3.142	1	0		1
1.906	0.7	2.199	0.837	4.192	1.155	0.521		1.38
2.437	0.6	1.885	0.775	4.593	1.209	0.71		1.56
3.211	0.5	1.571	0.707	5.044	1.267	0.917	1	1.792
4.402	0.4	1.257	0.633	5.533	1.327	1.136	4a	2.096
6.456	0.3	0.943	0.548	6.088	1.392	1.381	4b	2.54
10.737	0.2	0.628	0.447	6.743	1.465	1.666	4c	3.277
24.102	0.1	0.314	0.316	7.568	1.552	2.023	4d	4.911

[0026] It can be seen that even a moderate degree of taper can lead to significant reduction in maximum force. Suitably, the pumps of the invention will be designed such that the reduction in force is at least 30%, preferably at least 40% and more preferably of the order of 50% as compared to a similarly sized parallel bore pump.

[0027] Methods of supplying gas or vapour using the pump described form a further aspect of the invention.

[0028] The invention will now be particularly described by way of example with reference to the accompanying diagrammatic drawings in which

Figure 1 is a section through a pump of the invention;
Figure 2 is an enlarged end view of a piston for use in the pump of the invention;
Figure 3 is an enlarged end view of a guide which may be used in the pump of the invention; and
Figure 4 shows diagrammatically the proportions of a housing which would, in a typical bicycle pump require a fraction of only 0.4 (Figure 4a), 0.3 (Figure 4b), 0.2 (Figure 4c) and 0.1 (Figure 4d) of the force required in a conventional cylindrical pump.

[0029] In Figure 1, a housing 1 is provided with an internal bore 2 which tapers downward towards an outlet 3. A compressible piston 4 is accommodated within the bore 2. The piston 4, which may be made of a deformable elastomeric or rubber material, is broadly cup shaped having a flat circular base 5 and an annular inclined side wall 6 (Figure 2). An edge portion of the side wall 6 is in sealing contact with the internal surface of the bore 2 (Figure 1).

[0030] A piston rod 7 is attached to the base 5 of the piston 4. The piston rod enters the housing 1 through an opening in an end wall 8 of the housing 1. A guide 9 is mounted on the piston rod 7 behind the piston 2. The guide comprises a series of outwardly projecting elements or fingers 10 which are of equal length mounted equidistantly around a ring 11 which surrounds the piston rod 7 (Figure 3). The fingers 10 are biased such that end portions thereof contact the internal surface of the bore 2.

[0031] An axially projecting sleeve 12 is provided at the opening 8. The piston rod 7 passes through the sleeve 12. A handle 13 is provided at the end of the rod 7, for operating the pump.

[0032] Application of force to the piston rod 7 moves the piston 4 down the bore 2, forcing gas or vapour under pressure through the outlet 3. As the piston 4 progresses through its stroke, it becomes compressed as a result of the decreasing size of the cross section of the bore 2. The side wall 6 of the piston 4 is deformed inwardly as a result of the constricting action of the bore 2.

[0033] The fingers 10 of the guide rotate with respect to the ring 11 such that they do not prevent the motion of the piston 4 but keep it in axial arrangement to the housing 1.

[0034] The smaller cross sectional area presented by the piston 4 as it progresses through the housing makes the piston 4 increasingly more effective at overcoming the pressure and thus reduces the amount of force required to move the piston as compared to a conventional cylindrical pump.

[0035] The pump illustrated in Figure 1 would be expected to require only half the force required by a cylindrical pump (see Table 1 above). The relative dimensions of pump housing which are expected to give even greater reductions in force requirements are illustrated in Figure 4.

Claims

1. A gas or vapour pump comprising a compressible piston slideably accommodated in a bore in a housing wherein the cross sectional area of the bore and the piston decreases towards an outlet of the pump.

2. A gas or vapour pump according to claim 1 wherein the ratio of the cross sectional area of the bore at the outlet region of the housing to the cross sectional area at the opposed end of the housing is in the range of from 1:1.2 - 1:25.

3. A gas or vapour pump according to claim 1 or claim 2 wherein the bore of the housing is circular.

4. A gas or vapour pump according to claim 5 wherein the bore of the housing has a substantially frustro-cone shape.

5. A gas or vapour pump according to any one of the preceding claims wherein the compressible piston comprises an elastomer or rubber material.

6. A gas or vapour pump according to any one of the preceding claims wherein the piston is shaped so as to facilitate compression thereof within the housing, such as a cup shape where the rim of the cup is in sealing contact with the internal surface of the bore.

7. A gas or vapour pump according to any one of the preceding claims which further comprises means to ensure that the piston remains axially centred within the housing throughout its stroke.

8. A gas or vapour pump according to claim 7 wherein the said means comprises a guide supported on a rod of the piston and arranged to contact the internal surface of the bore throughout the piston stroke.

9. A pump according to any one of the preceding claims which is a bicycle pump.

10. A method of supplying a gas vapour under pressure, said method comprising using a pump according to any one of claims 1 to 9.

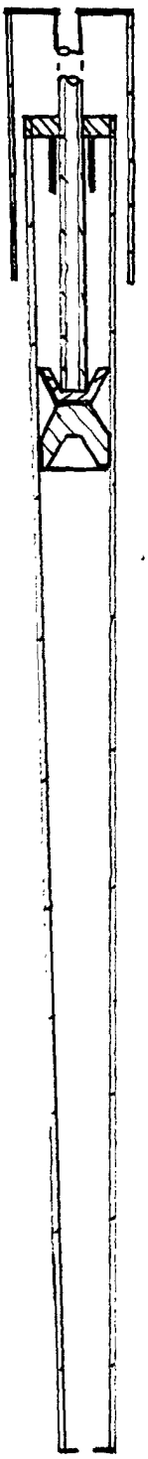

Figure 1

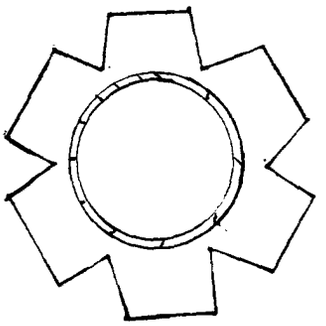

Figure 3

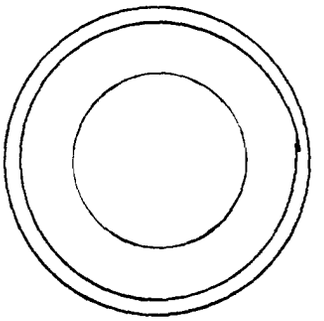

Figure 2

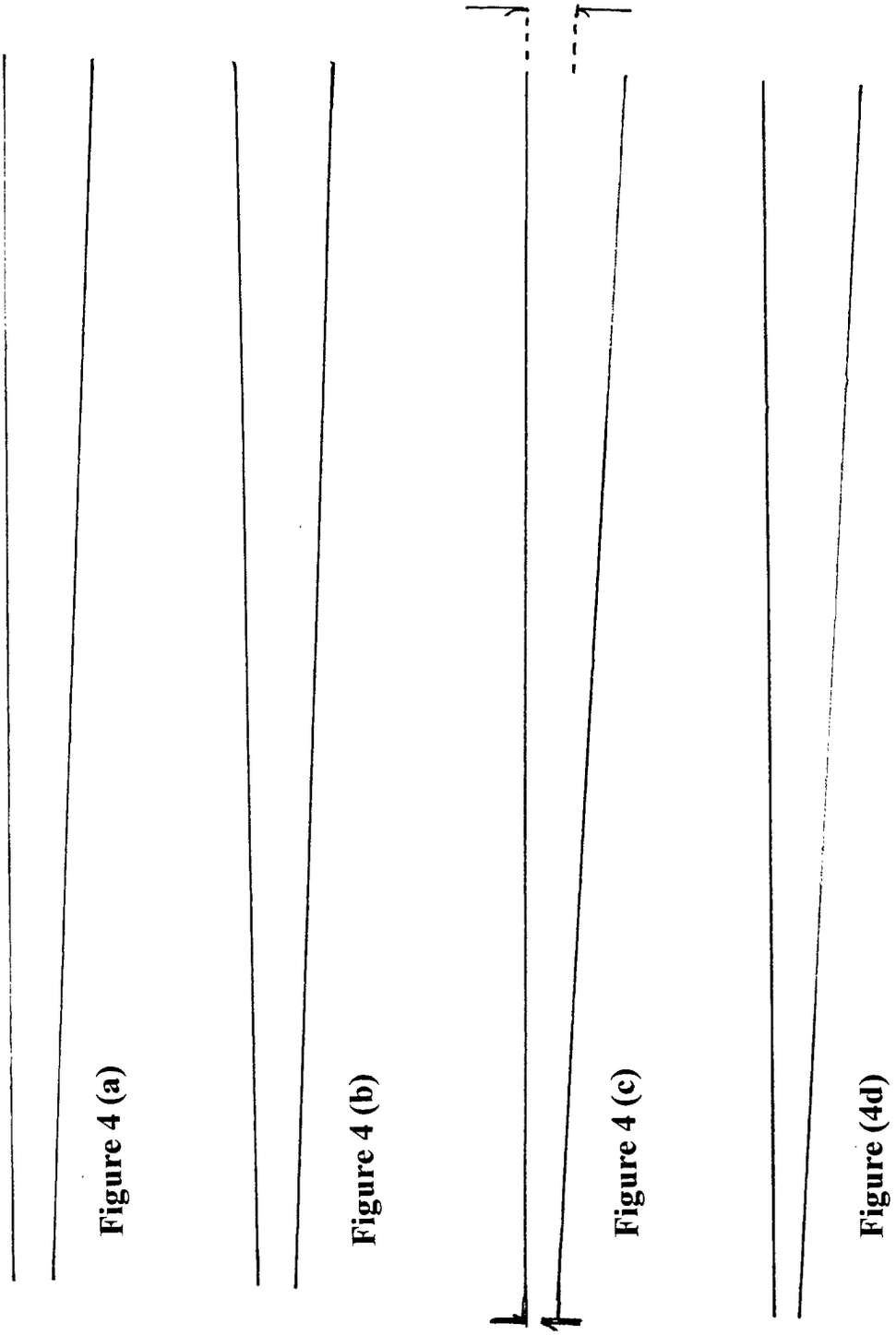

Figure 4 (a)

Figure 4 (b)

Figure 4 (c)

Figure (4d)

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EUROPEAN SEARCH REPORT

Application Number
EP 00 30 1134

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Y A	GB 997 662 A (BLUEMEL BROS.) 7 July 1965 (1965-07-07) * page 2, line 24 - line 45 * * figure 1 * ---	5,9,10 1,3,6	
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F04B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 July 2000	Kolby, L

CATEGORY OF CITED DOCUMENTS

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82