April 3, 1962 R. H. MERKLE 3,027,848

DIAPHRAGM PUMP

Filed July 13, 1959 2 Sheets-Sheet 1

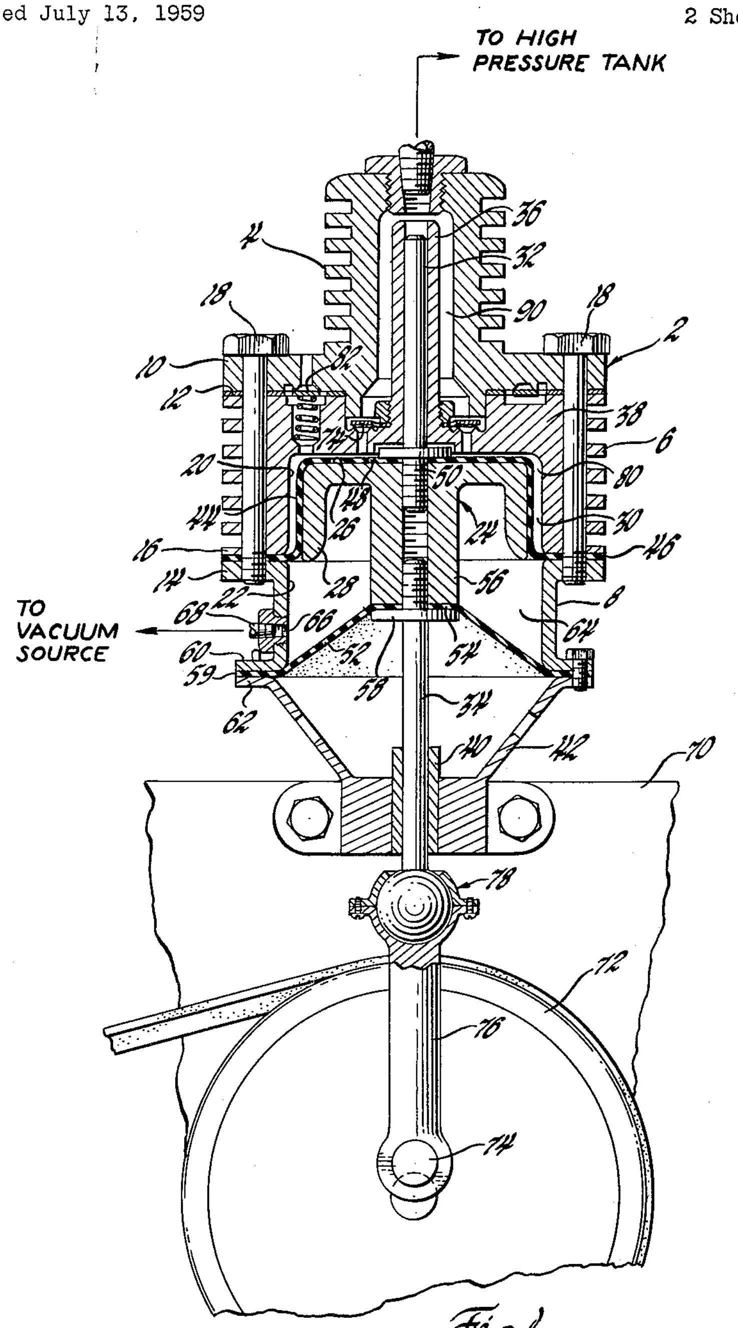

Fig. 1

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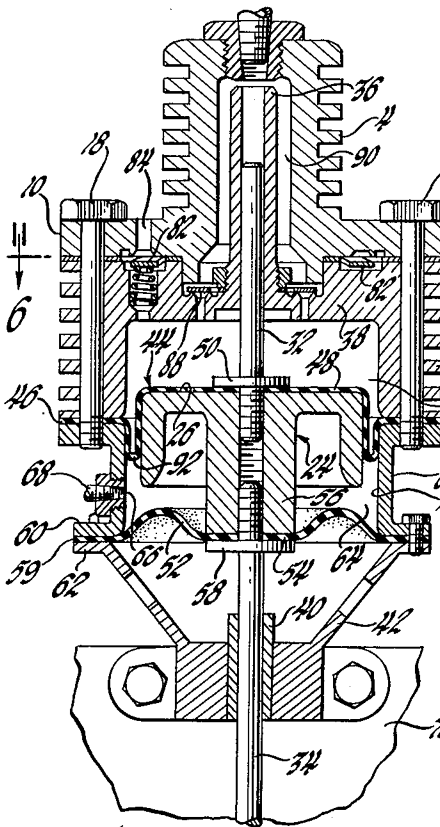

Fig.2

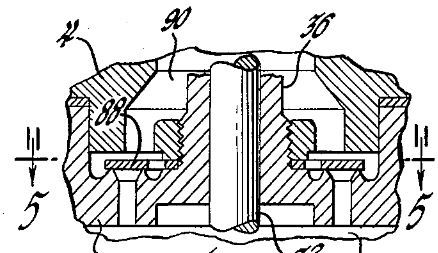

Fig.3

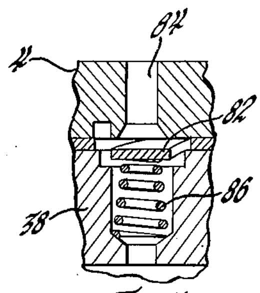

Fig.4

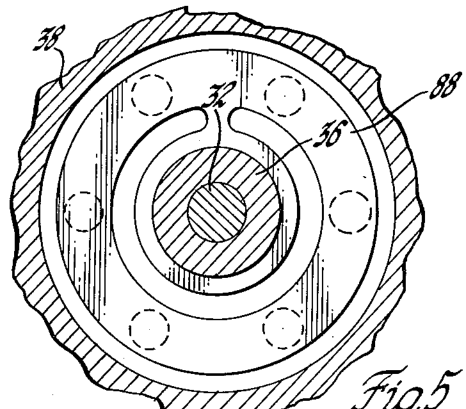

Fig.5

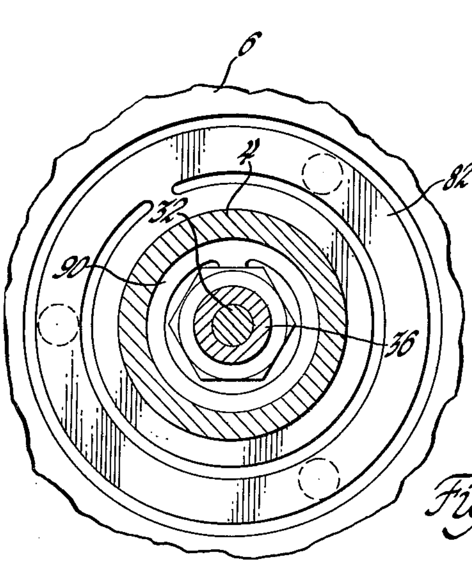

Fig.6

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DIAPHRAGM PUMP

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13 Claims. (Cl. 103—150)

This invention relates to pumps and more particularly to diaphragm pumps of the type wherein the diaphragm includes an intermediate annular portion which assumes a looped or folded configuration during portions of the cycle of operation of the pump.

Diaphragm type pumps have long been known in the art and have been adapted for a variety of uses. However, in general, the utility of such pumps has been somewhat limited in terms of maximum compression pressure owing to the fact that the stroke necessary to achieve a high compression ratio inherently requires an intermediate generally unsupported diaphragm portion which assumes varying folded configurations during a portion of the pump stroke between top dead center and bottom dead center. While such constructions superficially appear to present no problem, in practice, it is found that the intermediate looped portion buckles during the pump intake stroke due to the partial vacuum created in the compression chamber with the result that the actual efficiency of the pump is a mere fraction of the apparent efficiency.

In one form of pump of the type referred to above, a cylinder has reciprocably disposed therein a piston element of a diameter which provides a substantial annular interval between the piston skirt and the inner cylinder wall. A thin flexible membrane or diaphragm overlies the piston and has its peripheral edge secured to the cylinder wall at a suitable intermediate vertical level. The diameter of the membrane or diaphragm is sufficiently great so that with the piston at top dead center, all of the slackness in the diaphragm is removed. During all other displaced positions of the piston, the intermediate portion of the diaphragm is intended to assume a folded or depending loop configuration between the cylinder wall and the piston skirt. It will be evident that in a construction of the type described, the stroke of the piston and hence the theoretical compression ratio may be varied at will by selecting the appropriate vertical level for connection of the diaphragm periphery with the cylinder wall and dimensioning the diaphragm so that it is substantially taut when the piston is at top dead center. However, as previously indicated above, such pumps heretofore have been incapable of actually producing compression pressures of the order which are theoretically possible owing to the fact that the diaphragm intermediate portion fails to assume the proper looped configuration during the piston downstroke because of the partial vacuum formed in the compression chamber during the downstroke. The result is that the efficiency is not only relatively low, but in addition the diaphragm loop portion is subject to rupture, abrasion, and tearing caused by wedging between the cylinder wall and piston skirt.

An object of the present invention is to provide an improved diaphragm type pump.

Another object is to provide a folded diaphragm type pump wherein the actual compression efficiency is comparable to the apparent compression efficiency.

A further object is to provide a fluid pump of the type including a piston, cylinder, and diaphragm having an unsupported intermediate looped portion, wherein means are provided which prevent buckling of the looped portion during the intake stroke of the pump.

Yet a further object is to provide a pump having a compression chamber formed in part by a piston actuated

flexible diaphragm and including a sub-atmospheric chamber acting on the side of the diaphragm opposite that of the compression chamber to maintain the diaphragm in predetermined varying cross-sectional configuration throughout the entire pump stroke.

A still further object is to provide a device of the stated character wherein a vacuum chamber is formed between the pump diaphragm and a second diaphragm spaced from the pump diaphragm.

These and other objects, advantages, and features of the invention will become more fully apparent as reference is had to the accompanying specification and drawings wherein:

FIG. 1 is an elevational view, partly in section, showing a pump construction in accordance with the invention;

FIG. 2 is a fragmentary view similar to FIG. 1 showing the relative relation of parts when the pump piston is in an intermediate position between top dead center and bottom dead center;

FIG. 3 is an enlarged fragmentary view, partly in section, illustrating the construction of the exhaust valve of the pump;

FIG. 4 is an enlarged fragmentary view, partly in section, illustrating the pump intake valve;

FIG. 5 is a fragmentary plan view, partly in section, looking in the direction of arrows 5—5 of FIG. 3; and

FIG. 6 is an enlarged fragmentary plan view looking in the direction of arrows 6—6 of FIG. 2.

Referring now to the drawings and particularly FIG. 1, there is shown a pump structure **2** which in the illustrated embodiment takes the form of an engine driven air compressor adapted to supply a high pressure storage tank, not shown, such as used for vehicle pneumatic suspension, air brakes, etc.

Pump **2** includes a cylinder head **4**, cylinder **6**, and cylinder skirt **8**. Cylinder head **4** has a lower flange portion **10** which abuts the top wall **12** of cylinder **6**, while cylinder skirt **8** has a flange **14** which underlies the bottom wall **16** of cylinder **6**. Head **4**, cylinder **6**, and skirt **8** are secured together in axial alignment by circumferentially spaced bolts **18**. Reciprocably disposed within the cavity defined by the inner wall **20** of cylinder **6** and inner wall **22** of skirt **8** is a piston element **24** having a flat top surface **26** and a depending cylindrical skirt **28**. Piston **24** is dimensioned so that a substantial annular interval **30** exists between piston skirt **28** and the inner wall **20** of cylinder **6** and inner wall **22** of skirt **8**. Piston **24** is guided in a rectilinear path by means of axially aligned upper rod **32** and a lower rod **34**. Rod **32** is slidably received in guide sleeve **36** formed integrally on the top wall **38** of cylinder **6**, while lower rod **34** is slidably received in guide sleeve **40** mounted on the compressor support bracket **42**. Extending between and closing the annular interval between cylinder **6** and piston **24** is a flexible diaphragm **44**, the outer periphery **46** of which is clamped between the abutting bottom face of cylinder bottom wall **16** and the flange **14** of skirt **8**.

In accordance with one feature of the invention, the central portion **48** of diaphragm **44** is connected to the top wall **26** of piston **24** by means of a flange **50** formed on rod **32**. Since the lower end of rod **32** threadably engages piston **24**, it will be evident that as the rod is threaded into the piston, flange **50** compressively engages diaphragm portion **48** and thereby positively secures the diaphragm in position on the piston top wall.

In accordance with the principal feature of the invention, a second diaphragm element **52** is disposed across the lower open end of cylinder skirt **8** and has its central portion **54** clamped between the lower face of depending stem portion **56** of piston **24** and a flange **58** formed on rod **34**. Inasmuch as rod **34** is threadably secured to piston **24** in the same manner as rod

32, it will be evident that the connection provides a leak proof juncture between diaphragm 52 and depending stem 56 of piston 24. The outer periphery 58 of diaphragm 52, in turn, is clamped between the lower flange 60 of cylinder skirt 8 and an abutting flange 62 formed on the upper end of support 42. It will now be evident that diaphragms 44 and 52 cooperate to form a closed cavity 64 which is bounded by the inner wall 22 of cylinder skirt 8. In accordance with the present invention, this cavity is subjected to a predetermined sub-atmospheric pressure, which in the illustrated embodiment, is accomplished by the provision of a port 66 formed in the wall of cylinder 8 which is adapted for connection by a conduit 68 to any suitable source of vacuum, such as for example, the intake manifold of a vehicle engine, the usual vacuum pump associated with such engines, vacuum storage tanks utilized on vehicles equipped with power brakes or any other desired source. Obviously, cavity 64 may also be initially evacuated to a predetermined vacuum level and then sealed as by inserting a suitable valve, not shown, in conduit 68.

In order that the invention may be more clearly understood, description of the cycle of operation of the device follows. For the purposes of illustration, the compressor is shown mounted in a vehicle engine 70, which engine is provided with a crankshaft driven pulley 72. Pulley 72 includes a crankpin 74 which engages a connecting rod 76, the upper end of which is connected by a ball joint assembly 78 to the lower end of rod 34. Assuming that the compressor piston is initially in the top dead center position shown in FIG. 1, clockwise rotation of pulley 72 imparts downward movement to piston 24 and diaphragm 44. This downward movement creates a partial vacuum in compression chamber 80 which, in turn, causes the spring biased reed type intake valve 82 to move to the position shown in FIG. 4, opening intake port 84 and allowing movement of atmospheric air into compression chamber 80. As pulley 72 continues to rotate, piston 24 moves progressively downwardly as illustrated in FIG. 2, thereby increasing the volume of atmospheric air in compression chamber 80. Upon reaching bottom dead center, piston 24 reverses direction and travels upwardly, which movement instantly balances the pressure within compression chamber 80 and atmospheric air, thereby allowing spring 86 to seat reed intake valve 82. Further upward movement of piston 24 acts to compress the volume of atmospheric air contained in compression chamber 80 and discharge the same past reed type exhaust valve 88 into exhaust chamber 90 in cylinder head 4 from whence it passes to the high pressure tank, previously referred to. As soon as the piston returns to the top dead center position shown in FIG. 1, the cycle is repeated.

During the course of description of the cycle of operation, it was stated that introduction of atmospheric air into the compression chamber 80 is caused by creation of a partial vacuum therein. Although in prior art structures such partial vacuum would seriously degrade if not totally destroy the theoretical capabilities of the compressor by causing erratic folding and upward buckling of the free loop portion 92 of the diaphragm (FIG. 2), by virtue of the present invention, this loop portion is caused to retain the same progressively changing contour throughout the entire intake stroke, as occurs during the compression stroke, owing to the presence of sub-atmospheric pressure in cavity 64. Therefore, the actual efficiency of the compressor will correspond to the apparent efficiency. All that is required is the level of sub-atmospheric pressure in cavity 64 be slightly lower than the maximum sub-atmospheric pressure created in the compression chamber 80 during the intake stroke. With this pre-requisite satisfied, sufficient pressure differential exists at all times at opposite sides of diaphragm 44 to assure that the folded convolution 92 will always "track" properly and thereby assure maximum intake of air on the intake stroke.

In connection with the general features of compressor construction just described, it will be noted that in addition to overcoming the longstanding and heretofore totally unsolved problem of achieving optimum compression efficiency, the structure has additional benefits and advantages in terms of simplicity of fabrication, low cost and extraordinary life expectancy. For example, relatively little precision machining is required owing to the fact that the piston and cylinder have substantial clearance therebetween. Further, lubrication requirements are virtually eliminated. This latter feature is especially significant in view of the fact that compressor lubrication has heretofore been a major source of trouble owing to the fact that even a limited amount of contamination of air by the compressor lubricant ultimately results in system malfunction.

From the foregoing it will be seen that the present invention enables for the first time the practical achievement of compressor efficiency in a diaphragm type pump which heretofore has existed only in the theoretical realm.

While but one embodiment of the invention has been shown and described, it will be apparent that other changes and modifications may be made therein. It is, therefore, to be understood that it is not intended to limit the invention to the embodiment shown, but only by the scope of the claims which follow.

I claim:

1. In an air compressor of the type including a cylinder having a loosely fitting piston disposed therein, a rolling lobe diaphragm connecting said cylinder and piston, fluid pressure means acting on said diaphgram to maintain the lobe of the latter in a configuration assuring optimum displacement efficiency, said means comprising a sub-atmospheric chamber bounded on one side by said diaphragm.

2. The structure set forth in claim 1 wherein said sub-atmospheric pressure is at least equal to the maximum sub-atmospheric pressure created in the cylinder by the intake stroke of said piston.

3. In an air compressor having a compression chamber defined by a concentrically arranged cylinder and a loosely fitting piston, a rolling lobe diaphragm connecting said cylinder and piston, a sub-atmospheric cavity bounded on one side by said diaphragm and acting thereon to prevent buckling of the diaphragm lobe during the intake stroke of the piston.

4. In an air compressor having a compression chamber defined by a cylinder having a loosely fitting reciprocable piston disposed therein, a rolling lobe diaphragm connecting said cylinder and piston, a sub-atmospheric pressure containing cavity bounded on one side by said diaphragm and acting thereon to prevent buckling of the diaphragm lobe during the intake stroke of the piston, said cavity being bounded on another side by a second diaphragm.

5. The structure set forth in claim 4 wherein the central portion of the second diaphragm is connected to and deflectable with said piston.

6. A pump comprising a casing forming a compression chamber having an end wall provided with inlet and exhaust openings, a piston reciprocably disposed in said casing, said piston and chamber being dimensioned so as to form an annular interval therebetween, a rolling lobe diaphragm closing said annular interval and forming the other end wall of said compression chamber, and sub-atmospheric pressure means acting on said diaphragm lobe to urge the latter away from said compression chamber.

7. A pump comprising a casing forming a compression chamber having an end wall provided with inlet and exhaust openings, a piston reciprocably disposed in said casing, said piston and chamber being dimensioned so as

to form an annular interval therebetween, a rolling lobe diaphragm closing said annular interval and forming the other end wall of said compression chamber, and sub-atmospheric pressure means acting continuously on said diaphragm lobe to urge the latter away from said compression chamber.

8. A pump comprising a casing forming a compression chamber having an end wall provided with inlet valve and an exhaust valve, a piston reciprocably guided in said casing, said piston and chamber being dimensioned so as to form an annular interval therebetween, a rolling lobe diaphragm closing said annular interval and forming the other end wall of said compression chamber, and means forming a sub-atmospheric chamber around and below said piston adapted to act continuously on the surface of said diaphragm opposite the surface thereof facing the compresison chamber, whereby the lobe portion is maintained in a configuration assuring maximum pump displacement efficiency.

9. A pump comprising a casing forming a compression chamber having an end wall provided with inlet and exhaust valves, a piston reciprocably disposed in said casing, said piston and chamber being dimensioned so as to form an annular interval therebetween, a rolling lobe diaphragm closing said annular interval and forming the other end wall of said compression chamber, and an evacuated chamber in said casing below said diaphragm effective to prevent buckling of said diaphragm lobe during the intake stroke of said pump.

10. A pump comprising a casing forming a compression chamber having an end wall provided with inlet and exhaust valves, a piston reciprocably disposed in said casing, said piston and chamber being dimensioned so as to form an annular interval therebetween, rectilinear guide means for said piston formed in part on said casing, a rolling lobe diaphragm closing said annular interval and forming the other end wall of said compression chamber, and an evacuated chamber in said casing below said diaphragm acting on the latter to prevent buckling of said diaphragm lobe during the intake stroke of said pump.

11. In a device of the class described, a casing comprising a cylinder head, upper cylinder and lower cylinder connected in vertically stacked relation, a support for said casing connected to the base of said lower cylinder, a piston reciprocably guided in said casing, said piston being dimensioned so as to provide a substantial annular interval between the outer diameter thereof and the inner diameter of said cylinders, a diaphragm connected at its outer periphery between said upper and lower cylinders, said diaphragm having an intermediate loop portion closing the annular interval between said piston and cylinder and a central portion abutting the top of said piston and connected thereto, a second diaphragm having its outer periphery connected between the lower cylinder and said support, said second diaphragm extending across said piston and being connected thereto in vertically spaced relation from said first mentioned diaphragm thereby providing a closed cavity, and means for evacuating said cavity

to establish sub-atmospheric pressure therein sufficient to cause the lobe of said first diaphragm to assume the same progressively varying convolution during both downward and upward movement of said piston.

12. In a device of the class described, a casing comprising a cylinder head, upper cylinder and lower cylinder connected in vertically stacked relation, a support for said casing connected to the base of said lower cylinder, a piston reciprocably guided in said casing, said piston being dimensioned so as to provide a substantial annular interval between the outer diameter thereof and the inner diameter of said cylinders, a diaphragm connected at its outer periphery between said upper and lower cylinders, said diaphragm having an intermediate depending loop portion closing the annular interval between said piston and cylinder and a central portion abutting the top of said piston and connected thereto, a second diaphragm having its outer periphery connected between the lower cylinder and said support, said second diaphragm extending across said piston and being connected thereto in vertically spaced relation from said first mentioned diaphragm thereby providing a closed cavity below said piston, and means for evacuating said cavity to establish sub-atmospheric pressure therein sufficient to cause the lobe of said first diaphragm to assume the same progressively varying depending convolution during both downward and upward movement of said piston.

13. In a device of the class described, a casing comprising a cylinder head, upper cylinder and lower cylinder connected in vertically stacked relation, a support for said casing connected to the base of said lower cylinder, a piston reciprocably guided in said casing, said piston being dimensioned so as to provide a substantial annular interval between the outer diameter thereof and the inner diameter of said cylinders, a diaphragm connected at its outer periphery between said upper and lower cylinders, said diaphragm having an intermediate depending loop portion closing the annular interval between said piston and cylinder and a central portion abutting the top of said piston and connected thereto, a second diaphragm having its outer periphery connected between the lower cylinder and said support, said second diaphragm extending across said piston and being connected thereto in vertically spaced relation from said first mentioned diaphragm thereby providing a closed cavity surrounded by said lower cylinder, and means for evacuating said cavity to establish sub-atmospheric pressure therein sufficient to cause the lobe of said first diaphragm to assume the same progressively varying depending convolution during both downward and upward movement of said piston.

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