Oct. 27, 1959 C W. MUSSER 2,910,006

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Filed Feb. 26, 1958 2 Sheets-Sheet 1

Fig. 1.

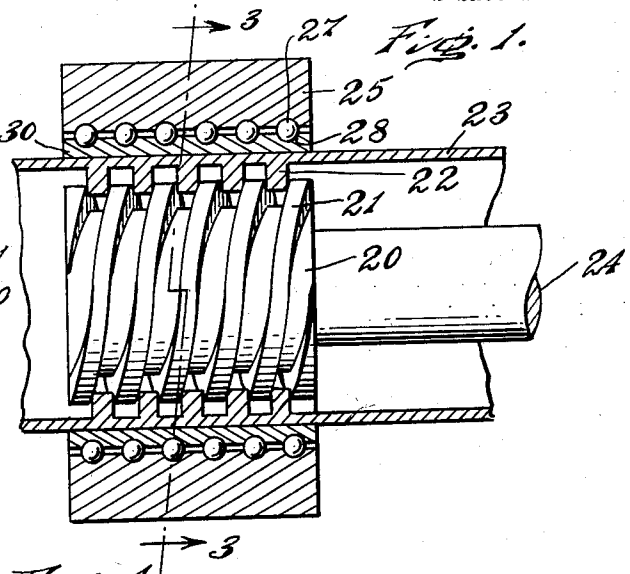


Fig. 2.

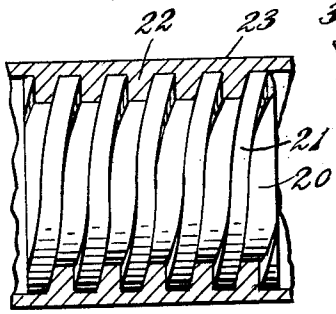


Fig. 3.

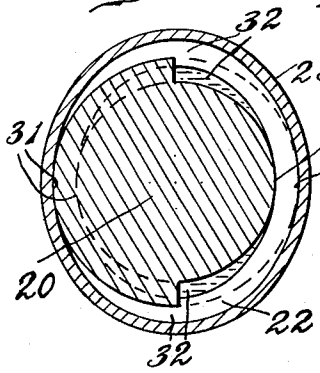


Fig. 4.

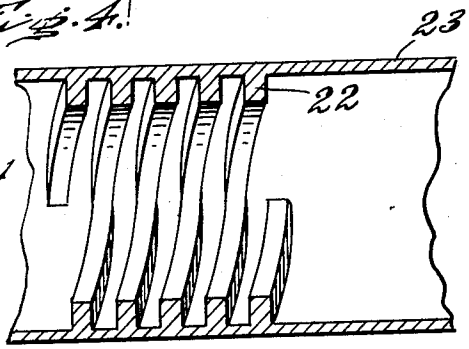
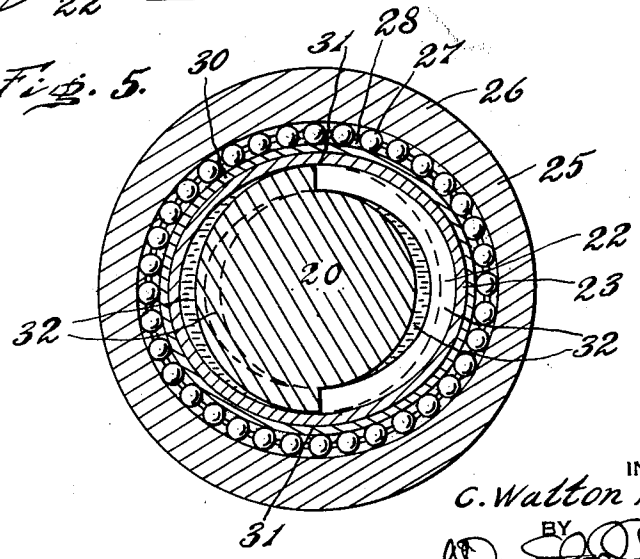


Fig. 5.



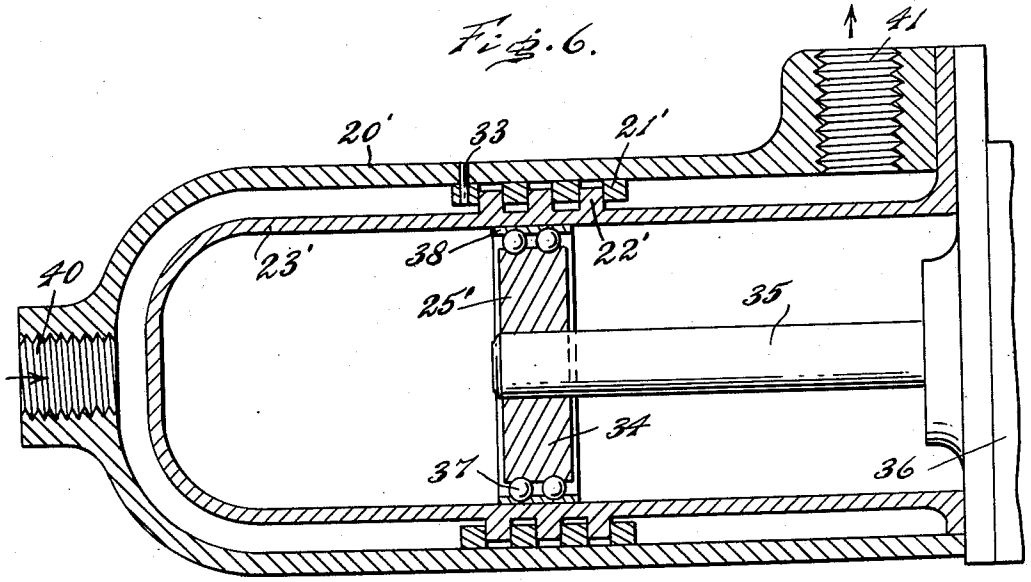
INVENTOR
C. Watton Musser
BY
ATTORNEYS.

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Fig. 6.



INVENTOR
C. Watton Musser
BY
ATTORNEYS.

United States Patent Office 2,910,006 Patented Oct. 27, 1959

2,910,006

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C Walton Musser, Beverly, Mass., assignor to United Shoe Machinery Corporation, Flemington, N.J., a corporation of New Jersey

Application February 26, 1958, Serial No. 717,659

12 Claims. (Cl. 103—149)

The present invention relates to positive displacement pumps.

A purpose of the invention is to operate a positive displacement pump through a hermetically sealed wall of a vessel.

A further purpose is to provide a positive displacement pump that has no appreciable sliding friction at the pumping surfaces.

A further purpose is to displace flexible threads into engagement with cooperating threads of the same thread form and lead at a plurality of circumferentially spaced points, interspersed by areas of nonengagement, and to advance the areas of engagement around the circumference of the flexible threads.

A further purpose is to preload the flexible threads at the points of engagement to increase the pressure of contact and obtain a better seal against leakage.

A further purpose is to utilize square tongue and groove threads for the pump.

A further purpose is to prevent rotation between the threads.

Further purposes appear in the specification and in the claims.

In the drawings I have chosen to illustrate a few only of the numerous embodiments in which my invention may appear, selecting the forms shown from the standpoint of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a fragmentary partially diagrammatic, axial section in the plane of the major axis of the elliptoid through a pump of the invention.

Figure 2 is a view corresponding to a fragment of Figure 1 showing a section at the minor axis of the elliptoid.

Figure 3 is a transverse section of Figure 1 at the line 3—3, showing only the interior pump parts.

Figure 4 is a view of the interior of the hermetically sealed vessel omitting the inner pump element shown in section corresponding to Figure 1.

Figure 5 is a fragmentary transverse section similar to Figure 3, showing how the pumping action continues through the cycle, and including the wave generator.

Figure 6 is an axial section of a modified form of the pump of the invention.

There is considerable need in the art for pumps which can be effectively operated through hermetically sealed walls and can therefore pump fluids which are extremely valuable or are very dangerous or subject to contamination. By the present invention it is possible to accomplish pumping through a completely sealed wall without danger of escape of the fluid being pumped and without likelihood of contamination.

The invention also offers the advantage that pumping can be accomplished without appreciable sliding contact between the pumping surfaces and therefore with less likelihood of wear.

The pump of the present invention embodies the principles of the strain wave linear actuator set forth in my copending application Serial No. 633,254, filed January 9, 1957, for Strain Wave Gearing-Linear Motion.

By deflecting the wall of a thin tube by a wave generator, a suitably helical thread preferably of square tongue and groove form is manipulated to progressively advance a trapped portion of liquid along the helix.

Inner and outer engaging threads are provided which have the same thread form and the same lead, and preferably the thread form is rectangular or square. The tube is elliptoidally deflected to cause the threads to bottom on the minor axis at the top, bottom and sides of the teeth, and seal off the fluid and these sealing points are caused to travel around the pump.

Considering the drawings, I there illustrate an inner pump element **20** having exterior helical threads **21** suitably of the square tongue and groove form, but permissibly of other suitable form as desired. The exterior threads **21** mate with interior threads **22**, which in the form shown are integrally provided on the interior of a hermetically sealing tube **23**. While it is convenient to make the threads **22** part of the tubular wall **23**, it will be understood that it is unimportant from the standpoint of the present invention whether the internal threads are part of the wall **23** or separate from it, but in any case they should not be permitted to rotate with respect to the exterior threads **21**.

As a convenient means of stopping rotation, but without intention to limit to this form, I show a shaft **24** in Figure 1 interconnecting with stationary members not shown. Any other suitable means of stopping relative rotation may be used as desired.

The interior threads are of the same thread form as the exterior threads and have the same lead as the exterior threads.

A wave generator **25** surrounds the hermetically sealing wall **23** and flexibly deforms it into an elliptoidal contour. The particular form shown embodies an outer race **26** having elliptoidal interior curved grooves **27** which cooperate with elliptoidal outer grooves **28** on an inner race **30**, whose exterior and interior contour is elliptoidal and which shapes the flexible tube **23** into an elliptoidal shape.

Thus as best seen in Figure 3, it will be evident that the inner and outer threads mate and seal at a plurality of circumferentially spaced points **31**, which correspond to the minor axis of the elliptoid, while at spaced points corresponding to the major axis of the elliptoid there are four crescent-shaped fluid portions **32** where the threads are nonmating. In other words there is a point of maximum outward deflection at the major axis and at this point the trapped fluid has the largest cross section. On the minor axis there are sealing areas and where desired these sealing areas are improved by applying extra stress or preload to the wave generator to press down very firmly between the mating threads at **31** or by overdeflecting the flexible element so as to slightly deflect the cooperating threaded element.

These four crescent-shaped curved portions filled with fluid are made to advance circumferentially along the helix angle of the threads from one end to the other by rotating the outer race **25** in any suitable way. It will be evident that in passing from one end of the threads to the other, there are numerous of these crescent-shaped increments which seal at the minor axis of the ellipse and these crescent-shaped "slugs" of fluid are caused to advance along the helix from one end to the other of the inner element **20**. The fact that these slugs are in series means that the seals act like a labyrinth packing, the total pressure drop being the sum of the pressure drops across the various seals.

It is a fact that the angular displacement of the portions

of the tube 23 will be greatest at the 45 degree point or intermediate between the major and minor axes. If the inner and outer threaded elements are made from material of high modulus of elasticity such as steel, the threads should be made with small clearance to allow for the axial displacement of the threads occasioned by the angular displacement of the 45 degree portion. This axial displacement is a function of the deflection, the diameter of the tube 23, and the lead of the threads. For a five inch flexible tube with a diametral deflection of ⅛ inch and a lead of 0.2 inch, the axial displacement is about 0.0004 inch and as a consequence the thread width should be about 0.0008 inch less than the tooth space width.

However, the axial displacement is a distinct advantage. This converts the sliding motion that would otherwise occur into almost pure rolling motion. It is clear that the contact points on the major and minor axes are of a rolling nature, but casual analysis might lead one to think that the thread side motion is strictly radial. However, since the radial deflection creates an angular displacement which must cause displacement due to the helix angle of the threads, only those portions of the deflected tube threads which have the greatest axial displacement will come into contact with the sides of the screw threads. At the 45 degree and 225 degree portions this will be at one side of the threads and at the 135 degree and 315 degree portions this wall be at the opposite sides.

In between these points the teeth will have clearance, and on the major and minor axes the teeth will be centered with the same amount of clearance on both sides. As the points of contact are circumferentially advanced many times as fast as the radial or circumferential slippage, the action is almost pure rolling.

Since the clearance is a very small amount, suitably less than 0.001 inch in the case referred to, no problems arise from leakage. In the above example the leakage path is an average of 0.0004 inch if the parts are made to have a metal to metal fit when deflected. Actually since the material, whether steel, stainless steel, bronze or otherwise is elastic, and particularly elastic where the parts other than the wave generator are made of elastomers such as rubber, synthetic rubber or elastomer plastic, and since the up and down contact points are 90 degrees or several inches apart, the clearance can be made less than this and the advantage of rolling contact will still exist as long as the parts have clearance however small in the undeflected condition.

The amount of fluid pumped is a function of the speed of rotation, the deflection, the diameter of the tube, the lead of the thread and the number of threads. It can be increased or decreased by altering any of these. For preloading of the threads where desired, the outer race 25 of the wave generator may be given the desired degree of flexibility.

In the form shown, it has not been necessary to restrain the threads against axial movement, but it will be understood that if the inner threads are separate from the tube and are restrained against relative rotary motion with respect to the outer threads, suitable provision to prevent axial motion as for example by internal collars will suitably be provided.

In case a screw of many threads is used, very effective pumping can be obtained under high pressures because of the labyrinth effect and the fact that numerous seals are obtained throughout the length.

In operation it will be evident that once the device is assembled by inserting the interior thread in the exterior thread and deflecting the exterior thread as by forcing the wave generator over the tube 23, or separating the wave generator and fastening it together by suitable fastenings, it is merely necessary to turn the wave generator in the desired direction to make the pump operate.

In the form of Figure 6, there is a reversal of the positions of the parts in Figures 1 to 5. In Figure 6 the flex tube 23′ has external threads 22′, and these mate with threads 21′ of the same lead positioned on the inside of a rigid housing 20′. The threads 21′ are suitably formed of piston ring spring material which is urged against the inside of housing 20′, and anchored thereto at one end as by pin 33 through the housing at the low pressure end, so that the pump pressure is free to compress the thread 21′ longitudinally. The wave generator 25′ is inside the flex tube 23′ and consists of an elliptoidal rigid inner race 34 on shaft 35 of motor 36, the race 34 engaging balls 37 which also ride in outer elliptoidally deflected race 38 which engages the inside of flex tube 23′ and deflects the threads 22′ on flex tube 23′ into engagement with threads 21′ at a plurality of circumferentially spaced areas, with intermediate nonmating areas as already explained. Inlet is provided at 40 and outlet is provided at 41 with respect to the pumping space.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure and method shown, and I, therefore, claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a pump, an inner threaded pump element, an outer threaded pump element coaxial with the inner element, having its threads cooperating with the inner element and having the same lead, and wave generator means engaging one of the elements for bringing the threads into full engagement at circumferentially spaced areas with intervening areas of nonengagement and advancing the areas of engagement along the threads.

2. In a pump, an inner threaded pump element, an outer flexible threaded pump element coaxial with the inner element, whose threads cooperate with those of the inner element and which have the same lead, and wave generator means surrounding the outer pump element, bringing the threads of the outer element into full engagement with the inner element at a plurality of circumferentially spaced points with intervening points of nonengagement and advancing the points of engagement along the circumference of the threaded elements.

3. In a pump, an inner pump element having rectangular threads, an outer pump element coaxial with the inner element, having rectangular threads of the same lead cooperating with the inner pump element, one of the pump elements being flexible, and a wave generator engaging and deflecting one of the pump elements into full engagement with the threads of the other at a plurality of circumferentially spaced areas with intervening areas of nonengagement and advancing the areas of engagement around the circumference.

4. In a pump, an inner pump element, having exterior threads, an outer pump element coaxial with the inner element, having interior threads of the same thread form and same lead as the threads on the inner pump element, one of the pump elements being flexible, and a wave generator engaging and deflecting the flexible pump element into full engagement of its threads with the other pump element at a plurality of circumferentially spaced areas with intervening areas of nonengagement and by deflection spring loading the flexible element at the areas of thread engagement.

5. In a pump, a hermetically sealed wall, inner threads within the wall, means within the inner threads and coaxial therewith, said means being provided with external threads of the same thread form and the same lead as the inner threads and cooperating with the inner threads, and a wave generator engaging the outside of the wall, deflecting the inner threads into full engagement with the external threads at a plurality of circumferentially spaced areas, with intervening points of nonengagement, and ad-

vancing the engaging points around the circumference of the outer wall.

6. A pump of claim 5, in combination with means for preventing relative rotation between the inner threads and the external threads.

7. In a pump, an outer element, an inner element, inner and outer coaxial threads of the same lead, one thread on one element and the other separate from but engaging against the other element, and means engaging one of the elements for deflecting one thread into full engagement with the other at a plurality of spaced areas.

8. A pump of claim 7, in which the separate thread comprises a helical spring strip.

9. In a pump, a flex tube, external threads on the outside of the flex tube, coaxial helical threads of the same lead cooperating with the external threads, a rigid member surrounding and engaging said helical threads, and wave generator means deflecting the flex tube to bring its threads into full engagement with said helical threads in a plurality of circumferentially spaced areas.

10. In a pump, inner and outer coaxial means, cooperating outer and inner threads of the same lead on said inner and outer coaxial means respectively, and wave generator means acting on one of the coaxial means for deflecting it radially for bringing one set of threads into full engagement with the other at a plurality of spaced areas.

11. A pump of claim 10, in which the inner threads deflect.

12. A pump of claim 10, in which the outer threads deflect.

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