

Nov. 9, 1954

M. B. SENNET

2,693,763

NONPOSITIVE SCREW PUMP OR MOTOR

Filed Oct. 25, 1951

4 Sheets-Sheet 1

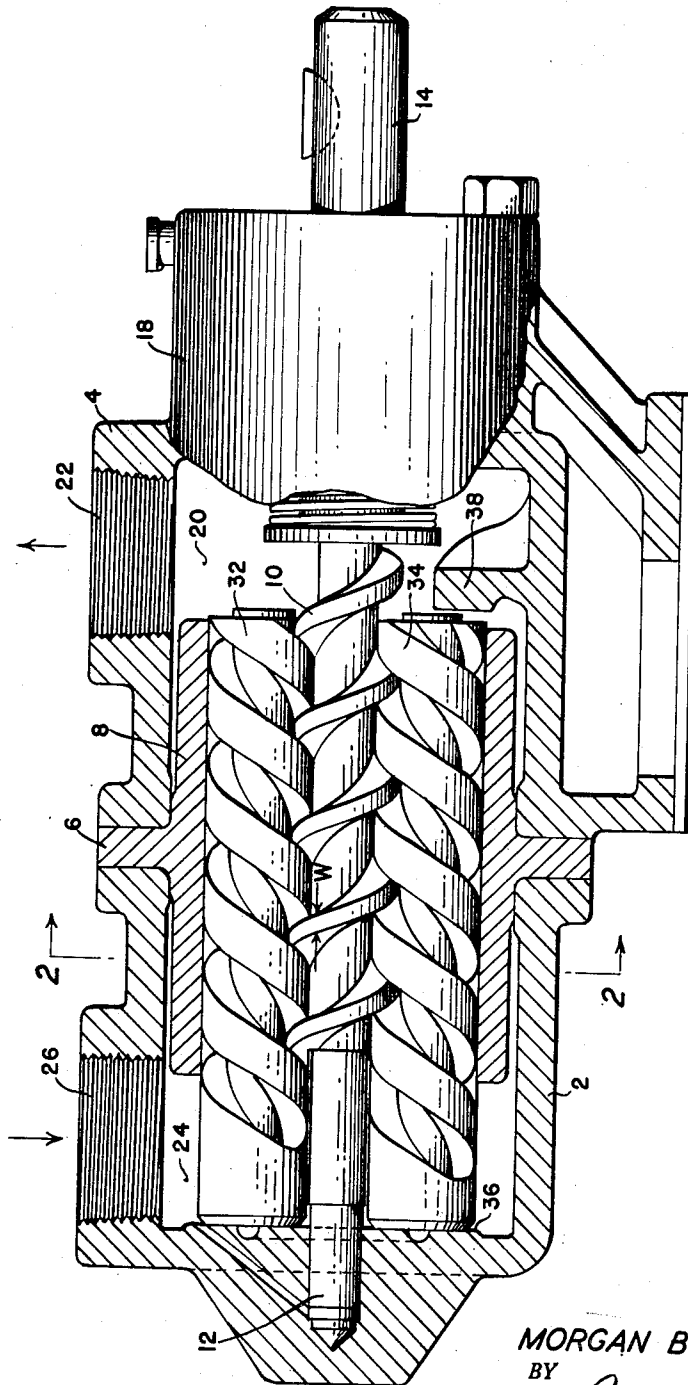


FIG. 1.

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4 Sheets-Sheet 2

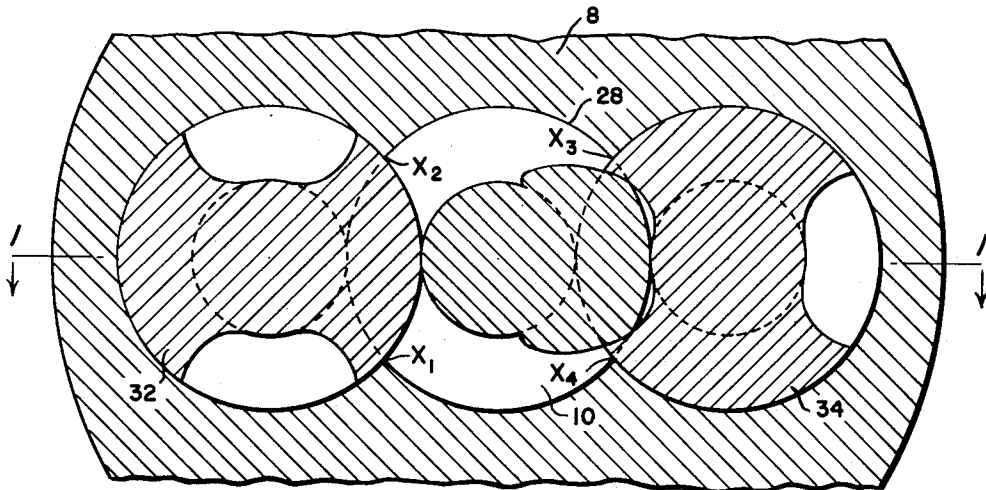


FIG. 2.

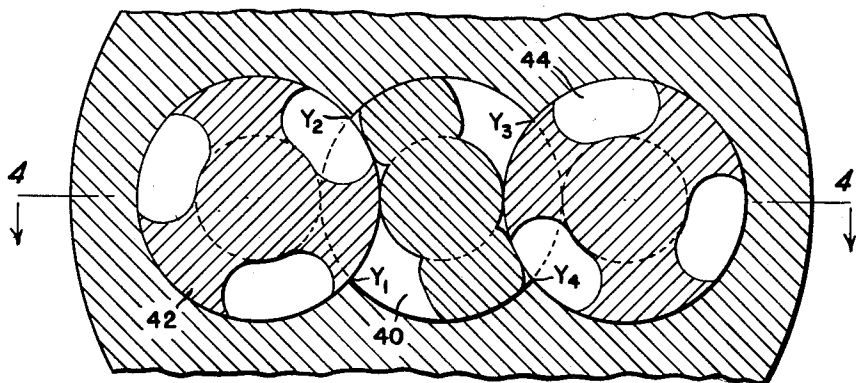


FIG. 5.

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4 Sheets-Sheet 3

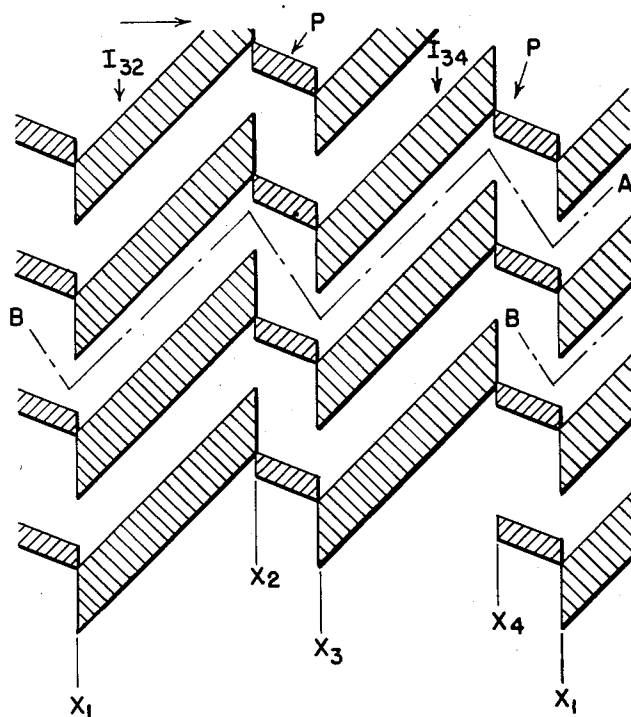


FIG. 3.

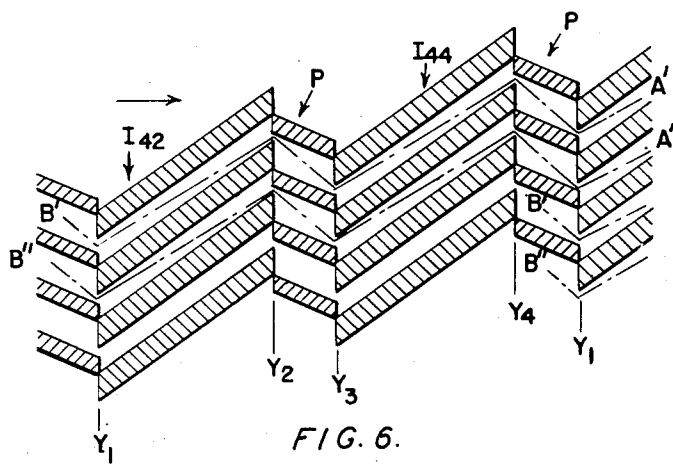


FIG. 6.

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4 Sheets-Sheet 4

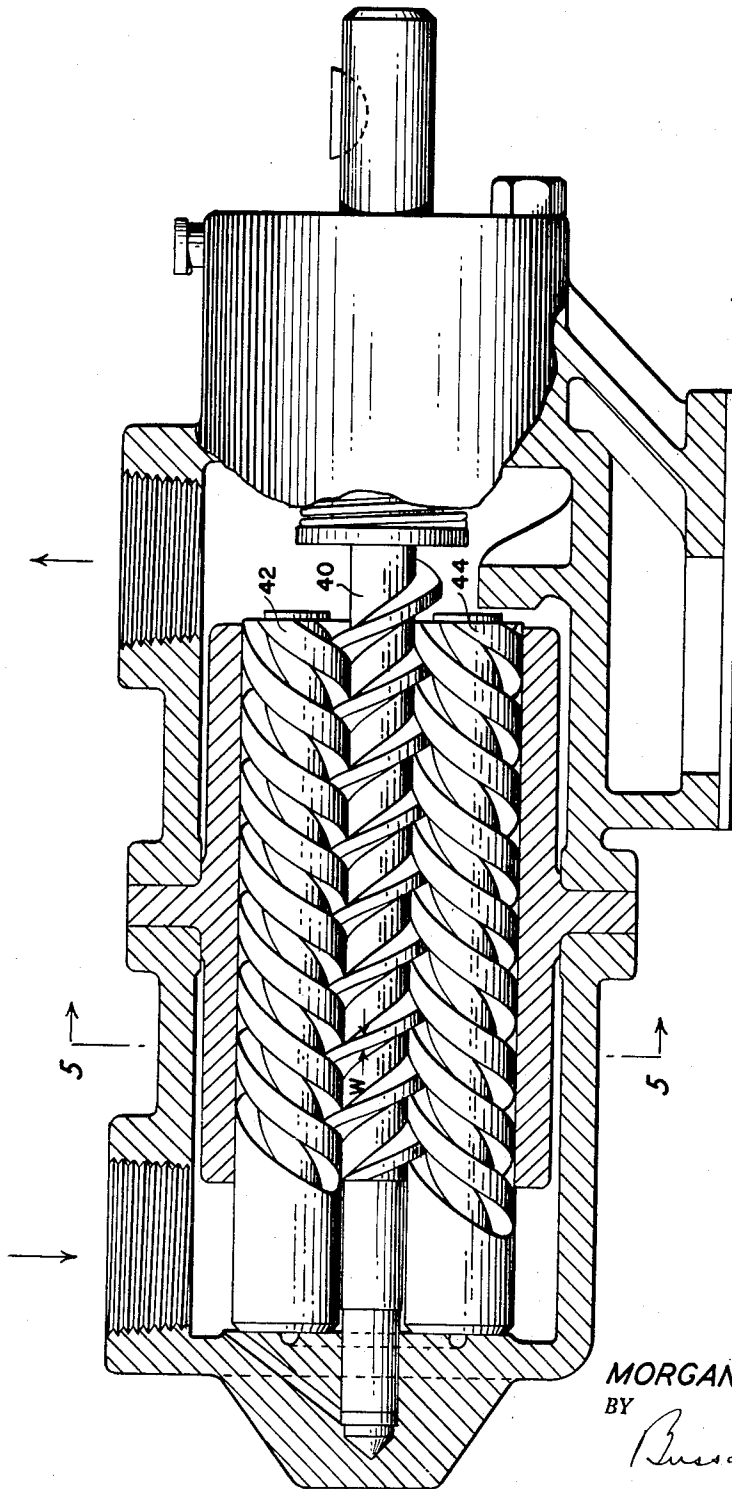


FIG. 4.

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2,693,763

NONPOSITIVE SCREW PUMP OR MOTOR

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Application October 25, 1951, Serial No. 253,093

10 Claims. (Cl. 103—128)

This invention relates to non-positive screw pumps and motors and has particular reference to such pumps or motors capable of operating at very high speeds without gearing.

In the patent to Montelius No. 1,698,802, dated January 15, 1929, there is disclosed a type of screw pump which is positive in its displacement characteristics. Positive screw pumps of this type have gone into widespread use and are capable of operating at very high speeds. Such positive pumps have been particularly used for the pumping of oils though they have also been used for the pumping of aqueous liquids or semi-solid materials. In the pumping of oils which contain little or no volatile constituents, these positive screw pumps are highly satisfactory in operation and are very quiet. However, if the oil or other liquid being pumped contains dissolved air or gas or constituents of easy volatility, difficulties are encountered in the way of production of vibration which is of such intensity as not only to be objectionable from the standpoint of noise but may reach proportions such that damage is done to pipe connections, and the like, due to the shock of intense vibration.

The reason for this condition may be rather easily explained from theoretical considerations. In the positive screw pumps referred to there are essentially closed chambers which, in effect, travel lengthwise of the axes of the screws, being first open to the inlet for the reception of the fluid being pumped, then closing to entrap this fluid, and finally opening to the discharge side of the pump, forcing the fluid outwardly at a substantially uniform rate. The suction pressure may be low particularly under conditions of high speed of pump operation and, in fact, the pressure at the inlet may be considerably less than the supply pressure, for example atmospheric pressure on the supply tank or sump. In fact, these pumps are self-priming so that the liquid is commonly raised from a low level to the pump level. It follows that as the liquid enters the pump and the chambers close, previously dissolved air or other gas may separate from the oil and furthermore highly volatile constituents may separate with the result that the chambers close on what is a mixture of oil and a gas or vapor which latter may account for a certain percentage of the volume of the chamber. As the chamber progresses to the discharge due to the action of the pump, since it is essentially closed, except to the extents which will be referred to in greater detail hereafter, the low intake pressure is maintained and the gas or vapor remains separated, the actual volume of liquid being to some extent less than the volume of the travelling chamber. When the chamber opens to the discharge pressure it is therefore subjected to a sudden compression action which will tend to condense vapors or force separated fixed gases into solution. The result is an intense hammering action occurring every time one of the chambers opens to the discharge and this serves as the source of the vibration referred to.

To solve the problem offered by the foregoing conditions it has been proposed to provide a booster pump for example of centrifugal type for the purpose of building up an initial pressure at the inlet side of the positive screw pump so that separation of vapor or gas from the liquid being pumped is prevented. This, however, involves special constructions which, of course, increase the cost of the pumping unit.

In the Montelius patent referred to above there are discussed the requirements on the relationships between the numbers of threads on intermeshing screws required

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for the attainment of positive displacement. A violation of these requirements will result in an inherent non-positive characteristic of a screw pump provided with intermeshing screws even though the thread shapes are generated in accordance with the principles of the patent, and irrespective of the effective axial length of the pump which may be defined as the length which involves intermeshing of screws within intersecting bores in a housing, i. e. the length through which passages are defined bounded by thread and root surfaces and the walls of the bores.

What is meant by a positive pump may be first made clear. A commercially practical positive pump necessarily involves running clearances between the screws and the bores of the housing and additionally involves some slight clearances which will permit leakage by reason of the practical necessity for avoiding sharp edges on the threads of the idler screws which edges are generally flattened or rounded by the provision of so-called lands. If in a practical pump the screws were held stationary, there would be in a pump of the positive variety some leakage from the high pressure to the low pressure side because of the clearances just referred to. Nevertheless, this leakage is of very small amount compared with the normal delivery of the pump and is particularly small in amount as consideration is given to the pumping of viscous oils. Leakages due to the clearances just referred to, therefore, are not considered as detracting from the positive nature of a so-called positive screw pump. Theoretically, if these clearances were eliminated there would be no leakage and if the pump was stationary it would provide a positive barrier for flow from its high pressure side to its low pressure side.

In the case of a non-positive pump the leakages due to clearances occur just as in the case of a positive pump but it is not such leakage which is of significance. Even if the clearances were eliminated from the non-positive type of pump which will be considered herein, it would be found that there would be a clear passage traceable through the grooves of the screws from the high pressure side to the low pressure side irrespective of the length of the housing provided. In other words, no matter how great the axial length of the non-positive pump, there would still be a clear leakage path with the degree of leakage controlled solely or substantially solely by the viscosity of the liquid being pumped and the pressure gradient across the pump.

In view of this free leakage path, it might seem that the non-positive pump would be relatively useless. However, if as described hereafter, the leakage path is quite tortuous and in particular at a minimum is such as to require a passage of the liquid at least once about the power screw, a pump is provided having highly desirable characteristics as follows:

Such a non-positive pump may be provided by screws having the same characteristics as those of positive pumps and capable of operating at very high speeds and without being interconnected by gearing. By reason of the tortuous leakage path, furthermore, the pump is capable of producing high pressures.

Considering the problem, referred to above, of vibration resulting from sudden compression of gas or vapor in the positive pump, the non-positive screw pumps in accordance with the invention do not suffer from this condition. Inasmuch as there is a free passage from the outlet to the inlet, there is along such passage a pressure gradient continuously varying from the outlet pressure to the inlet pressure. It follows, therefore, that liquid which is being progressed by the pump is not subjected to any sudden increase of pressure at a particular phase of the operation, but rather there is a continuous increase of pressure without the production of vibration due to a sudden pressure change. While, being non-positive, the pumps of the present invention are not as well adapted for priming under substantial lift conditions as the positive pumps, nevertheless they involve self-priming characteristics to a substantial and generally practical extent.

It sometimes happens that a positive screw pump is called upon to perform under conditions in which the flow may possibly be cut off on the outlet side. In such cases to avoid damage it is necessary to provide some

relief mechanism which, considering the high pressures at which discharge is generally effected may be required to be of rather special and costly nature. In the absence of such a relief device destructive damage may easily occur since if the flow is interrupted the effect is practically that of interposing a mechanical barrier suddenly to the rotation of the positive pump screws.

The non-positive screw pumps are not subject to this condition. Whereas the amount pumped per revolution of the positive pump is substantially the same irrespective of the head pumped against, except for slight increase of leakage through clearances, and accordingly the characteristic of quantity pumped against head is a substantially straight horizontal line, in the case of the non-positive pumps provided in accordance with the invention there is a drooping characteristic, the quantity delivered decreasing with the head pumped against. The slope of this characteristic depends upon the viscosity and the speed of operation and while there is a slope so that at some particular pressure the quantity pumped will be zero, nevertheless, for many practical applications the characteristic is highly satisfactory and what is required even aside from possible considerations of insurance against damage in the event that the flow from the outlet is suddenly stopped. If the latter conditions occurs, the pressure merely rises to the cut-off pressure without damage to the pump.

While pumps have been primarily referred to heretofore, it will be evident that the invention is applicable to screw motors which may also be desirably non-positive particularly under conditions of a positively delivered supply but the possibility that rotation of the motor shaft may be forcibly impeded. It will, therefore, be understood that the following description refers to motors as well as pumps though for simplicity of reference the description will generally refer only to pumps.

The broad object of the invention may be stated to be the provision of non-positive pumps and motors of satisfactory characteristics capable of operating at high speeds and without interconnecting gearing.

Subsidiary objects of the invention relate particularly to details of construction and criteria for the production of the most desirable pumps and motors. These subsidiary objects as well as the attainment of the primary object will become apparent from the following description read in conjunction with the accompanying drawings, in which:

Figure 1 is an axial section through a pump illustrating one embodiment of the principles of the invention, the section being taken on the plane indicated at 1—1 in Figure 2;

Figure 2 is a transverse section through the screws taken on the plane indicated at 2—2 in Figure 1;

Figure 3 is a diagram which will clarify the nature of the flow path involved in the pump of Figures 1 and 2;

Figure 4 is an axial section through another pump embodying the invention;

Figure 5 is a transverse section through the screws taken on the plane indicated at 5—5 in Figure 4; and

Figure 6 is a diagram which will clarify the nature of the flow path involved in the pump of Figures 4 and 5.

Briefly stated, the improved pump or motor comprises a power screw and two idlers, the power screw having either one or two threads and each of the idler screws having two threads when the power screw has one thread or three threads when the power screw has two threads. Involved in the invention is the adoption of a proper minimum "length" of the screw assembly used, this term being hereinafter defined.

Referring first to Figures 1 and 2, there is illustrated therein a typical pump provided in accordance with the invention, it being understood that this or a very similar structure may be utilized as a motor. A casing is provided by castings 2 and 4 secured to each other with the interposition of the flange 6 of a housing member 8 which is provided with intersecting cylindrical bores for the reception and guidance of the working screws. The power screw is indicated at 10 and is provided with a shaft extension 12 at one end received in a bore in the casing member and with a shaft extension 14 which is mounted in a bearing associated with a sealing arrangement located with the extension 18 of the casting 4. These arrangements form no part of the present invention but are shown and described in detail in my application Serial No. 117,535, filed September 24, 1949, now Patent

No. 2,640,430, dated June 2, 1953. The shaft extension 14 provides for the input of power if the device is operated as a pump or for power output if it is operated as a motor. For simplicity of description it may be assumed that what is illustrated in Figures 1 and 2 constitutes a pump. The discharge chamber 20 at one end of the screw assembly delivers pumped liquid through the outlet 22, the liquid being received through the inlet 26 into the inlet chamber 24 at the other end of the screw assembly.

The power screw 10 is received in a cylindrical central bore 28 of the housing member 8 with which there intersect two cylindrical bores of the housing member 8 in which are located the two idler screws 32 and 34. These screws at their left-hand ends bear at 36 on a surface of the casing member 2. At their other ends they are free but limited in axial movement by abutment members one of which is indicated at 38 in Figure 1.

As indicated in the drawings, the power screw 10 has one thread and each of the idler screws has two threads. As will be evident, to provide meshing the idler screws are of a hand opposite that of the power screw 10.

Both the power screw and the idler screws are designed in accordance with the principles set forth in said Montelius patent, and desirably are so proportioned as to minimize the production of mechanical wear between them in accordance with the disclosure of Montelius patent 1,965,557, dated July 3, 1934. The operating characteristics of the pump may be best made clear by reference to Figure 3.

Figure 3 may be best understood by considering that it represents, from a purely diagrammatic standpoint a section of slightly more than a complete circuit about the power screw. Referring to Figure 2 in conjunction with Figure 3, it will become evident that Figure 3 is a development of a section taken on an axial surface just inside the peripheries of the screws along a path from X₁ about the outer portion of idler 32 to X₂, thence to X₃ about the power screw 10, thence about idler 34 to X₄ and back finally about the power screw to X₁. The segmental sections of the power screw are then indicated at P, while the segmental sections of the idler screws are indicated at the I's provided with subscripts corresponding to the idlers.

Referring to Figure 3, assume rotation of the power screw in the direction of the arrow at the top of this figure. Under this assumption the inlet to the pump will be at the bottom of the figure and the outlet will be at the top of the figure. The liquid will be progressed upwardly by the dynamic action of the screw threads.

That the pump is non-positive will become evident by considering the path AB noting that starting at X₁ and returning to X₁ the point B is located in the next groove of the screws below A. From the diagram it will be evident that irrespective of the lengths of the screws this path will be continuously open and will provide a tortuous leakage path from the outlet end of the set of screws to their inlet end. This path, however, is so tortuous, as may be recognized particularly from the figure, that the pump has a very effective dynamic action and, if of proper length, is capable of producing a quite substantial head.

Consideration may now be given to the question of proper length of the screws. By "length" is meant the effective length through which the screws are in mesh and are also properly surrounded by the housing to form a closed path. Stated otherwise the length here under consideration is that axial extent through which sections of the type indicated in Figure 2 would exist. The screws may be longer than the housing member such as 8 which surrounds them; or alternatively the housing length may be greater than the extent in which all of the screws are in mesh. The overhanging portions of the screws or housing are of no significance, proper pumping action of effective type occurring in the length which has been just indicated as the effective length.

By considering the contacts between the screws it will be found that, first assuming a symmetrical arrangement of the idlers about the power screw, a complete circuit of the power screw by the liquid to follow a leakage path will be required if the effective length of the pump, as above defined, is given by the following expression:

$$M = \frac{5P}{2} + W$$

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In the above expression,

M is the minimum effective length of mesh and enclosure of the screws to insure that liquid passing from outlet to inlet must make at least a complete circuit of the power screw;

P is the pitch, equal to the lead of each screw divided by the number of its threads; and

W is the axial width of the top of the power screw thread.

If the minimum effective length is less than this, it will happen that in some positions of the screws a path may be found from outlet to inlet which will make less than a complete circuit of the power screw. This possibility is undesirable giving not only an absence of full effectiveness of the screw arrangement in terms of producing maximum head for a given speed of operation, but will also give rise to pulsations by virtue of the less effective pumping action whenever the screws attain a configuration which gives the shorter path just mentioned.

The assumption of a minimum effective pump length for a symmetrical array of idler screws applies, however, to an asymmetrical array, since it will be found that, if an asymmetrical array is used, the minimum length would have to be greater than that given by the above expression to avoid a leakage path in certain positions of the screws which would provide less than a complete circuit of the power screw. Actually, symmetrical arrays are most desirable to avoid the existence of unbalanced lateral thrusts on the screws.

The dynamic action of the pump will be evident from consideration of Figure 3 which clearly indicates that in a complete circuit about the power screw the leakage circuit involves four orifices representing restriction to backward flow and also abrupt changes in the direction of the flow path. It is as a result of this that the described pump is capable of producing, particularly at high speeds, large heads. Increase of the effective length above the minimum adds rapidly to the dynamic pumping action by providing additional restrictions to, and abrupt changes of the backward leakage flow path. While therefore there is slip as compared with a positive pump there is highly effective pumping action against large pressure gradients and, in fact, as indicated above, the pump is self-priming in the sense that it can produce a considerable head when pumping air or other gas.

The two idler arrangement is particularly advantageous in securing smooth pumping action since the two idlers are out of phase, i. e. with respect to particular relationships to the power screw they are out of phase and in the case of a symmetrical arrangement that are 180° out of phase.

Referring now to Figures 4, 5 and 6 these are respectively similar to Figures 1, 2 and 3 but show an alternative pump or motor having characteristics very similar to that of the earlier figures. The construction is substantially identical and it will be noted that Figure 4 shows the structural elements of Figure 1 with the exception that the power screw 40 has two threads and each of the idlers 42 and 44 has three threads.

Figure 6 is a development similar to Figure 3, the section being taken on an axial surface just inside the peripheries of the screws along a path from Y₁ about the outer portion of idler 42 to Y₂, thence to Y₃ about the power screw 40, thence about idler 44 to Y₄ and back finally about the power screw to Y₁. The segmental sections of the power screw are indicated at P while the segmental sections of the idler screws are indicated at the I's provided with subscripts corresponding to the idler.

Again as in the previous case, assuming rotation of the power screw in the direction of the arrow at the top of this figure, under this assumption the inlet to the pump will be at the bottom of the figure and the outlet will be at the top of the figure. The liquid will be progressed upwardly by the dynamic action of the screw threads.

That the pump is non-positive will become evident by considering the path A'B' noting that starting at Y₁ and returning to Y₁ the point B' is located in the second groove of the screws below A'. This, it will be noted, is somewhat different from what appears in Figure 3 and Figure 6 shows a second path A''B'' in an intermediate set of screw grooves. Thus there are two parallel paths through the screws. From the diagram it will be evident that, irrespective of the lengths of the screws these paths will be continuously open and will

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provide tortuous leakage paths from the outlet end of the set of screws to their inlet end. This path, however, is so tortuous, as may be recognized from the figure, that the jump has very effective dynamic action and if of proper length is capable of producing a quite substantial head.

Considering effective length as above defined for this pump, it will be evident that the effective length will be given by the following expression

$$M=4P+W$$

In this expression M is the minimum effective length as above defined, P is the pitch and W is the axial width of the top of the power thread.

The considerations involved are similar to those previously described in all respects except for the presence of the two parallel paths through the screws. The pump has quite similar operating characteristics.

The two pumps may have their effective lengths defined in a common fashion by the expression

$$\frac{P}{2}(3n+2)+W$$

in which P is the pitch of the screws, n is the number of threads on the power screw and W is the axial width of the top of the power screw thread. The value of n in the case of the pump of Figure 1 is 1 and in the case of the pump of Figure 4 is 2.

What is claimed is:

1. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having not more than two threads having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having a number of threads one greater than the number of threads on the first mentioned screw, each of the threads of the last mentioned screws having concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

2. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having not more than two threads having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having a number of threads one greater than the number of threads on the first mentioned screw, each of the threads of the last mentioned screws having concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, the length of the assembly of the housing element and said screws within which the screws are in complete mesh and surrounded by the housing being at least equal to

$$\frac{P}{2}(3n+2)+W$$

in which P is the pitch of the screws, n is the number of threads on the first mentioned screw, and W is the axial width of the top of a thread of the first mentioned screw, and means defining inlet and outlet fluid passages communicating with said bores.

3. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having only a single thread having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having two threads, each of the threads of the last mentioned screws having concave flanks, the threads of said screws having cylindrical top

portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

4. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having only a single thread having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having two threads, each of the threads of the last mentioned screws having concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, the length of the assembly of the housing element and said screws within which the screws are in complete mesh and surrounded by the housing being at least equal to

$$\frac{5P}{2} + W$$

in which P is the pitch of the screws, and W is the axial width of the top of the thread of the first mentioned screw, and means defining inlet and outlet fluid passages communicating with said bores.

5. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having only two threads having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having only three threads having concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

6. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having only two threads having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having only three threads having concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, the length of the assembly of the housing element and said screws within which the screws are in complete mesh and surrounded by the housing being at least equal to

$$4P + W$$

in which P is the pitch of the screws, and W is the axial width of the top of a thread of the first mentioned screw, and means defining inlet and outlet fluid passages communicating with said bores.

7. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having at least one thread having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having only two threads

having concave blanks, differing by one from the number of threads on said first mentioned screw, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

8. A screw device of the type described comprising a housing element provided with a central bore and an even number of additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having an odd number of threads, each of which threads has convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having a plurality of threads, each of which last mentioned threads has concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

9. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having at least one thread having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having only three threads each of which threads has concave flanks, with the number of threads on said first mentioned screw not exceeding the number on each of said last mentioned screws, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

10. A screw device of the type described comprising a housing element provided with a central bore and two additional bores intersecting said central bore, the axes of all of said bores being parallel, a screw in said central bore having only a single thread having convex flanks, a screw in each of said additional bores intermeshing with the first mentioned screw and having at least one thread having concave flanks, the threads of said screws having cylindrical top portions substantially engaging with a running fit the cylindrical walls of said bores, and the peripheral thread edges of each screw substantially engaging the thread flanks of a meshing screw, and defining axially bounded tortuous passages extending about said screws and progressing axially as the screws revolve, and means defining inlet and outlet fluid passages communicating with said bores.

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