June 20, 1950 G. RATHMAN 2,511,878

SCREW PUMP

Filed Nov. 2, 1946 2 Sheets-Sheet 1

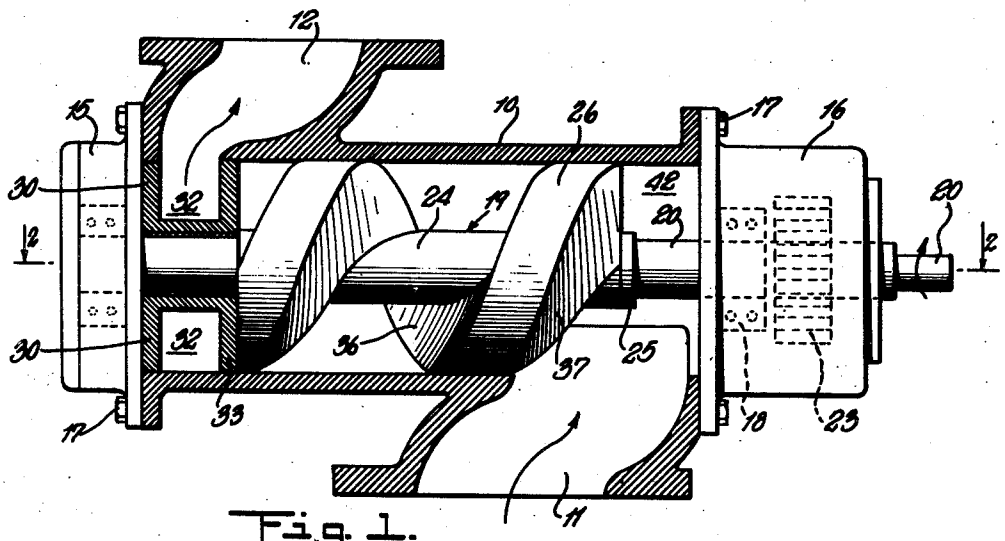



Fig. 1.

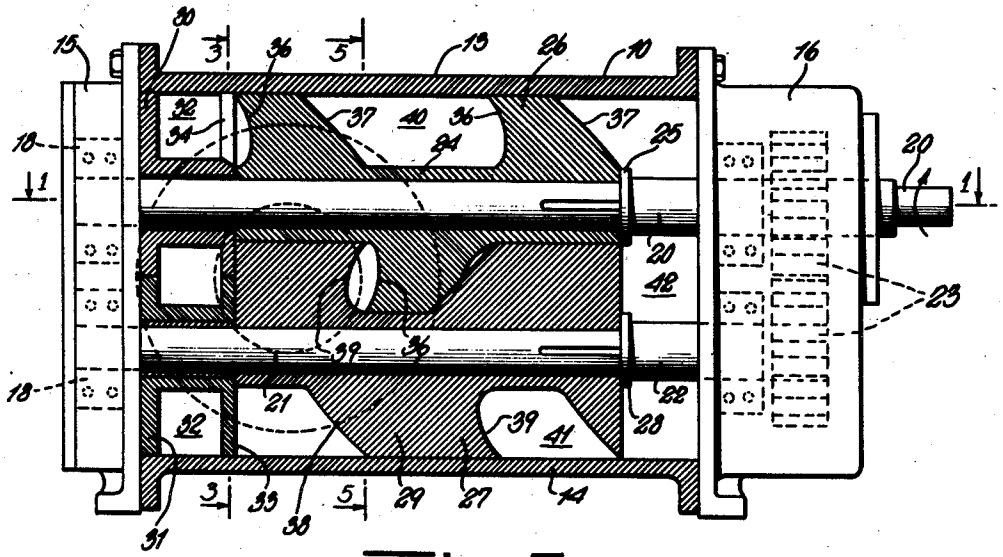



Fig. 2.

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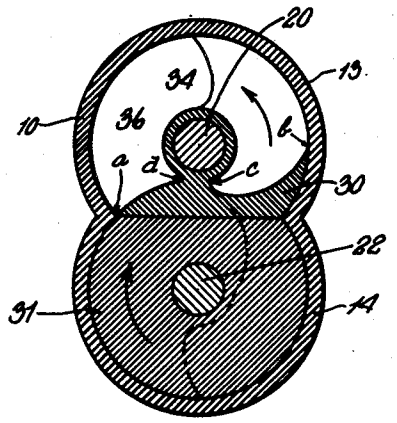



Fig. 3.

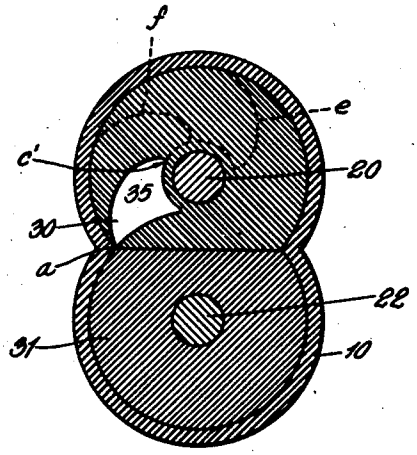



Fig. 4.

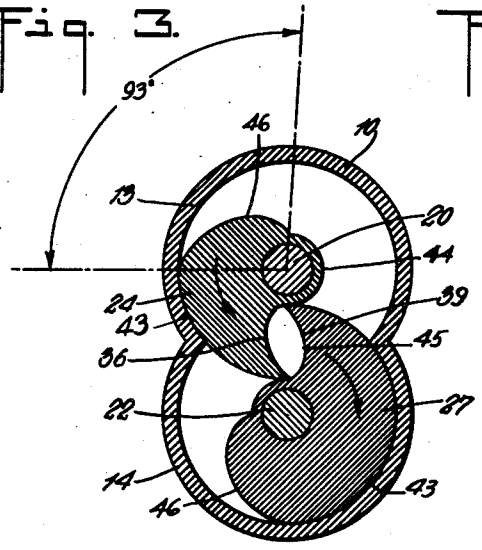



Fig. 5.

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# UNITED STATES PATENT OFFICE

2,511,878

## SCREW PUMP

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Application November 2, 1946, Serial No. 707,384

14 Claims. (Cl. 230—143)

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The invention relates to a screw pump of the type which includes two helically ribbed rotors, one usually called a discharge rotor and the other called a mating rotor; and which rotors are in intermeshed engagement and organized for passing, or for being passed by, a compressible or expansible fluid, specifically air or other gas. The invention is a development of a similar form of pump disclosed in my co-pending application entitled "Screw pump," Serial No. 511,083, filed November 20, 1943 (now Patent No. 2,460,310 dated February 1, 1949).

In this, as well as in the device of my earlier application, the primary object is to provide a highly efficient type of screw pump capable of maintaining a constant flow of the gas or other medium passed therethrough without objectionable surging or other variable pressure conditions in the fluid at the discharge end of the pump.

The primary object of the present disclosure is still further to improve the efficiency of screw pumps of the type above identified; to retain the advantages above recited and at the same time to simplify and thus reduce the manufacturing cost of such pumps specifically in the form of valvular outlet control disclosed in the earlier application.

In both the previous disclosure and in this disclosure, the fluid at the high pressure end of the mating rotor is blocked off from direct escape from the system and must flow into the discharge rotor and hence out from the system through the high pressure end of the discharge rotor. In the co-pending application the discharge is controlled by a valvular device composed of two apertured coacting valve elements, one fixed to the casing and the other to the discharge rotor and turning therewith to open the high pressure end of the discharge rotor once for each rotation. This method of utilizing a distinctive valve in controlling the pump discharge is sometimes called the "valve method."

In the device herein disclosed that valve element which in the earlier device rotates with the discharge rotor has been discarded and the pressure developed at the high pressure end of the discharge rotor is controlled by a valvular mechanism which does not include a separate and distinct rotative element and is controlled solely by reason of the preset configuration and volumetric discharging capacity of a fixed discharge port which is opened and closed periodically by the rotation of the discharge rotor alone. In distinction from the valve method of the prior application, the present disclosure for setting

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the discharge pressure is called a "port method."

Briefly, the present disclosure distinguishes from the prior art in that the intermeshing threads of both rotors, or the screw elements of both rotors, are convex on one side, concave on their opposite sides; the threads intermesh with a concave side of one thread facing the concave side of the other thread, and particularly distinguishes from the prior art in that the discharge opening faces the concave side or face of the thread of the discharging rotor.

Various other objects and advantages of the invention will be in part obvious from an inspection of the accompanying drawings and in part will be more fully set forth in the following particular description of one form of mechanism embodying the invention, and the invention also consists in certain new and novel modifications of the preferred construction and combination of parts hereinafter set forth and claimed.

In the accompanying drawings:

Fig. 1 is a plan view of a preferred embodiment of the invention with the casing shown in longitudinal section and taken on the line 1—1 of Fig. 2;

Fig. 2 is a view in side elevation of the device shown in Fig. 1 with the casing shown in longitudinal section and taken on the plane indicated by the line 2—2 of Fig. 1;

Fig. 3 is a view in cross section taken on the line 3—3 of Fig. 2, looking inwardly towards the discharging rotor and showing a fixed discharge opening of maximum discharging capacity and thus of least pressure transmitting capacity;

Fig. 4 is a similar view in cross section, also taken on the line 3—3 of Fig. 2, but showing a fixed discharge opening of minimum discharging capacity and thus of maximum pressure transmitting capacity, and

Fig. 5 is a view in cross section taken anywhere along the length of the intermeshing screws and in the instant case taken on the line 5—5 of Fig. 2.

In the drawing there is disclosed a pump casing 10 wide open at opposite ends and provided on one side with a fluid intake port 11 and on the opposite side with a fluid discharge port 12. Considered in cross section as shown in Figs. 3–5, the casing is a casting of an 8-shaped form and is composed in effect of two hollow cylinders 13 and 14 in partially overlapped relation and with their axes in parallel and offset relation. The open ends of the casing are closed by a pair of hollow heads 15 and 16 demountably secured to

the flanged ends of the casing by bolts 17. Journalled in sets of combination radial and end thrust bearings 18 contained in the heads 15 and 16 are a pair of rotors for forcing gases and other fluids from the intake port 11, through the casing and out through the discharge port 12.

One of the rotors 19, hereinafter referred to as the driving rotor, includes a shaft 20 which projects at one end exteriorly of the casing and of the head 16 and is adapted to be connected to a source of power arranged to turn the rotor as indicated by the arrow at the right of Fig. 1. The other rotor 21, hereinafter referred to as the driven rotor, includes a shaft 22 which is connected to the shaft of the driving rotor by means of a meshed gear set 23 contained in the head 16 and organized to drive the rotors at a one-to-one ratio.

The driving rotor 19 includes a discharge screw 24 keyed to the shaft 20 and held against movement towards the right of Figs. 1 and 2 by a stop shoulder 25 formed on the shaft. The screw 24 is formed with a single thread 26 of at least one convolution and has a running fit in the cylinder 13. Similarly the driven rotor 21 is provided with a mating screw 27 keyed to the shaft 22 and likewise held against a stop shoulder 28 fixed to the shaft 22. The screw is formed with a single thread 29, is of the same length as the driving screw 24 and has a running fit in the cylinder 14.

The screws are in intermeshing relation and in general the device as thus far described is of somewhat conventional construction.

Fitted into the left or high pressure and discharge end of the cylinders 13 and 14 are two hollow castings 30 and 31 through which loosely extend respectively the shafts 20 and 22. The screws are thus fitted axially between the castings 30 and 31 and the shoulder stops 25 and 28 on the shafts. It is noted that as the screws are not confined closely between heads of the casing there is no necessity to provide clearances for axial thermal expansion and contraction as is necessary in similar known forms of such pumps. These castings 30—31 are held between the screws 24 and 27 and the head 15. Casting 30 may be replaced by a similar casting with different types of discharge openings as hereinafter described, simply by removing the head 15 and substituting the proper port block 30. These castings coact to provide an annular channel 32 at all times open to the discharge port 12 as shown in Fig. 1. The inner wall 33 formed by the inner aligned sides of the two castings when so located in position provide a barrier for the entire left or discharge end of the mating screw 27 and at least for a portion of the left or discharge end of the discharge screw 24. The barrier wall 33 in the portion thereof formed by the block 30 is provided with a single discharge opening 34 which is located within the outlines of the axially projected cross section of the discharge screw 24 and leads therefrom into the channel 32 and therefrom to the outlet port 12 as shown in Figs. 1 and 2.

The arc length of the opening 34 and thus its discharging cross section and its relation to the end of the opening or channel in the discharging screw 24, controls the degree of compression which the pump is intended to impose upon the fluid passing therethrough. If it is the intent to use the pump simply as a liquid, air or gas propeller or transport and without intent to create any internal or built-in compression on the fluid, the opening is of the maximum extent as shown in Fig. 3. This maximum port opening begins at point *a* where the cylinder bores intersect and extends circumferentially and clockwise for about 220 degrees to the point *b*. From point *b* to point *c* the port outline terminates in a short concaved curve. The hub diameter circle hereinafter referred to as the root circle extends for about 320 degrees from point *d* to point *c*. The other end of the port outline terminates in a convex curve from point *d* to point *a* and coincides with the outside circumference of the mating screw 27. This means that the maximum arc length of the discharge opening 34 measured clockwise from *a* to *b* is about 220 degrees.

Where it is desired to utilize the device as a pressure creating pump the angular length of the opening 34 is reduced from the maximum suggested in Fig. 3 in the direction of rotation of the discharge screw 24. Fig. 4 illustrates one such high pressure discharge opening 35 and is formed in effect by advancing the curved edge *b*—*c* as shown in Fig. 3, counter-clockwise to the position *a*—*c'* in Fig. 4 forming a curvilinear triangle, and at about which point the maximum efficient working pressure ratio is obtained. In any case the area of the opening 35 is less than the discharging area of the groove 40, so that as the groove passes the opening the fluid under whatever pressures are developed in the discharging end of the groove, are released at that point in thread rotation where the groove 40 and outlet 35 register. Instead of blocking off the maximum opening 34 of Fig. 3, to a maximum extent as shown in Fig. 4, lesser arc lengths may be provided for the opening 35 as desired. The dotted lines marked *e* and *f* in Fig. 4 indicate the right ends of two such less openings. It is understood that gradually increasing the area 35 from that shown in Fig. 4 towards that shown in Fig. 3 gradually reduces the pressures imposed on the fluid passed by the pump. In practice that port block or casting 30 is used which contains the opening having an arc length, between that shown for opening 34 and that shown for opening 35, which will give the compression desired for the fluid as it is discharged from the pump.

It is particularly noted that one side of the thread or rib of each screw is concave in cross section and the opposite side is convex. For instance, and referring first to the thread 26 of the driving screw 19, it is seen the left side 36 as viewed in Figs. 1 and 2 is concave while the opposite or right side 37 is convex, or almost so. Referring to the thread 29 of the mating screw 27, the left side 38 is convex, or substantially so, while its opposite side 39 is concave. The screws are arranged so that when intermeshed as shown in Fig. 2 the concave side of the thread of one of the screws faces the concave side of the thread of the other screw. Likewise, of course, the convex side of one of the screws faces the convex side of its mating screw. For instance, the concave right side 39 of mating screw thread 29 faces the concave left side 36 of the discharge screw thread as clearly shown at the center of Fig. 2.

It is a particular feature of novelty of this disclosure that the concaved side 36 of the thread 26 forming the discharge screw faces the discharge opening 34 or 35 as the case may be. This means that the convex side 38 of the mating screw 27 faces the end barrier formed by the solid wall 33. It is a further refinement of the instant disclosure that the thread 26 of the discharge screw 24 is relatively thin in axial cross section of material with a relatively wide groove 40 be-

tween its turns. The thread 29 of the mating screw 27 is relatively thick in axial cross section of material with a relatively narrow groove 41 between its turns.

By using this arrangement the discharge rotor absorbs a larger percentage of power supplied to the pump than does the mating rotor and therefore the power transmitted through the timing gears 23 is much less than would be the case if the screws were of equal thread width. The arrangement herein illustrated results in a larger effective port area; reduces the amount of fluid necessary to be transferred from one rotor to the other and reduces the dynamic unbalance which exists in intermeshing rotating screws of the type herein disclosed.

The interior of the cylinders 13 and 14 in the length dimension thereof, between the inner wall 33 and the head 16, may be considered as providing screw containing spaces in which the screws freely rotate. Between the right ends of the screws and the head 16 is provided an intake chamber 42 of relatively large fluid transmitting capacity, open directly from the intake port 11 and forming the suction or intake end of the system and wide open to the intake ends of the two screws.

It is the intent herein to design the two rotors so that when installed in the pump they will be in static and dynamic balance. This is attained first by carefully machining the screws to approach as closely as possible this ideal condition, and thereafter each rotor is modified to obtain such balance either by adding or removing material from the screws following conventional practices in balancing high speed rotating bodies. It is of course possible to core out material from the mass of metal forming the threads and under some circumstances this is preferable as it provides screws less bulky than herein illustrated. In one instance metal was carefully removed from one side of each screw by a longitudinal grooving of the outer perimeter of each thread.

The rotors both have an outer peripheral surface of cylindrical curvature as shown at 43 to conform respectively to the curvature of the wall of the casing in which it rotates. The perimeter of the discharge screw 24 within the outlines of its associated thread 26, and the screw 27 within the outlines of its associated screw 29, each defines a root-circle or dedendum circle 44 concentric with its associated shaft. Each rotor exhibits in any section perpendicular to its axis, as shown in Fig. 5, a compound curved outline whose ends meet the peripheral circle 43. One outer portion of each of the compound curved outlines on one side of its associated root circle is concaved as shown at 45 and the other outer portion on the other side of its root circle is convex as shown at 46, with the part of the compound curve at its center connecting the concaved and convex portion forming the exposed part of the root-circle 44.

The convex portion 46 between the root-circle 44 and the peripheral circle 43 is a plane, half-heart-shaped involute curve substantially that of an Archimedean spiral and with an arc-length of about ninety to ninety-five degrees. In one position of the discharge rotor the curve 46 coincides with the curve *c—b* when the valve opening shown in Fig. 3 is in use, and coincides with the arc *a—c'* when the valve opening shown in Fig. 4 is in use.

In operation and assuming first that the wide open discharge port of Fig. 3 is in use for the



time being and that the discharge screw 24 is turning counter-clockwise and the mating screw 27 is turning clockwise as indicated by the arrows in Fig. 5, then the fluids are picked up from the large volume intake chamber 42 at the suction end of the device facing the free ends of the screws, and is moved thereby axially from right to left of Figs. 1 and 2 towards the discharge port 34. The part of the fluid which is picked up by the mating screw 27 is transmitted along the passage-way formed by the convex sides of the meshing screw threads and the wall of the cylinder 14 and then transversely to the discharge rotor which in turn discharges it from the pump through the port 34, channel 32 and port 12. There is thus provided a positive displacement type pump or blower of the puff-back type giving a square card performance.

Now assuming that a reduced area opening such as 35 of Fig. 4 is used and under the same conditions of screw rotation, the fluid transmitted through the pump is brought from zero compression in the chamber 42 and delivered under such pressure as may be determined by the arc length and location of the opening 35 through which the fluid, compressed by the screws, is discharged. In this case there is produced an internal or built-in compression in the last turn of the combined discharging, and in this case compressing, screw 24 resulting in a compression type card and giving higher efficiency than has been known heretofore in pumps of this character. The discharge is smooth, without shock or wire drawing.

While only one pair of intermeshing screws are shown, it is obviously within the scope of the disclosure, as taught by the prior art to duplicate the arrangement illustrated in Fig. 1 on opposite sides of the discharge conduit 32 as in the co-pending application, and it is possible to use two or three discharge screws of the type herein featured grouped about and meshing with one centrally disclosed mating screw. It is also possible as taught by the prior art to utilize the pump as a motor by admitting actuating expansive fluid into the pump through the normal discharge port 12 and discharging the fluid after it has expanded out from the pump through the normal intake port 11.

I claim:

1. A screw pump including a casing provided with an intake port and with a discharge port, a pair of rotors mounted on the pump for rotary movement, means connecting the rotors to drive one from the other at a one-to-one ratio, each of said rotors provided within the casing with a screw formed of a spiral thread, said screws being in intermeshing engagement at all times and power driven to advance fluids through the casing from the intake port through the discharge port, the spiral threads being each concave on one side and convex, or substantially so, on its opposite side, said screws related to cause the concave side of one thread to face the concave side of the other thread, and with the convex side of one thread facing the convex side of the other thread, the intake ends of both screws being wide open to receive fluids from the intake port, means forming a wall at the opposite or discharge ends of both screws and against which the screws squarely abut, said wall provided with a discharge opening leading to the discharge port and otherwise closed, said opening having an arc length not materially greater than 220 degrees, being within the axially

projected outline of one of the screws and facing the concave side of the thread of the last mentioned screw the groove of last mentioned screw in the end facing the wall having a discharge opening with an arc length in about 200°, said wall forming a barrier at the discharge end of the other screw to prevent flow from said other screw directly into the discharge port.

2. In a screw pump of the port type, the combination of a casing providing a screw containing compartment one end of which forms a fluid intake chamber, a pair of shafts extending in parallel relation through said compartment, means for driving one shaft from the other, each shaft provided at the inner side of the intake chamber with a stop shoulder, a pair of intermeshing screws one secured to one of the shafts and the other secured to the other shaft and abutting their associated stop shoulders, a wall extending across the compartment at the discharge ends of the screws, opposite the ends abutting the stop shoulders and against which the discharge ends of the said screws abut, said wall provided with a single opening located within the axially projected outline of one of the screws, having an arc length materially less than 220 degrees whereby the opening is periodically opened and closed by the screw which faces it, once for each rotation of said screw and said wall acting as a barrier at all times closing the discharge end of the other screw.

3. A screw pump including a casing provided with an intake port and a discharge port, a pair of rotors carried by the casing and mounted for rotary movement, means connecting the rotors to drive one from the other, each of said rotors provided within the casing with a screw including a single spiral thread having at least one convolution, the threads of said screws being in intermeshing engagement and operative to advance fluids through the casing from the intake port to the discharge port and to place the same under pressure, the spiral threads being each concave on one side and convex on the other side, said screws disposed with the concave side of one of the threads facing the concave side of the other thread, the intake ends of both screws being exposed to the intake port to receive the fluid therefrom, means forming a wall at the opposite or discharge ends of the screws, said wall provided with a discharge opening with an arc length less than the arc length of the concaved end of the screw which faces it leading to the discharge port, with said opening facing the discharge end of one of the screws and facing the concave side of the thread of said facing screw, and said wall otherwise closing the discharge ends of both screws.

4. In a device of the class described, the combination of a structure providing a screw containing chamber, means for propelling a fluid through the chamber and for imposing a pressure on the fluid as it is passed therethrough, said means including a screw having a spiral thread with a running fit in the chamber, one side of said thread being concaved, and a wall defining one end of said chamber and facing the concave side of the thread, the sole outlet from said chamber consisting of an opening in said wall whose cross-sectional area is less than the cross-sectional area of the groove between the turns of the thread at the discharge end of the screw, said opening thus controlling by reason of its cross-sectional area the degree of compression imposed on the fluid by said means.

5. In a device of the class described, the combination of a structure providing a screw containing chamber, means for propelling a fluid through the chamber, said means including a screw having a spiral thread with a running fit in the chamber, one side of said thread being concaved, a wall facing the concave side of the thread, defining one end of the chamber and against which the screw abuts, said wall provided within the axially projected outline of said thread with a discharge opening, the groove between the turns of the thread at the end thereof abutting the wall coacting with the opening to register therewith once for each rotation of the screw and to thus provide a valvular device for controlling the discharge of the fluid from the chamber, the arc length of the end of the groove facing the discharge opening being greater than the arc length of the opening.

6. In a screw pump, the combination of a pump casing provided with an inlet port, a discharge port and a screw chamber, means including a pair of intermeshing screws mounted in the screw chamber for propelling a fluid from the inlet port, through the screw chamber and out through the discharge port, means for driving one screw from the other at a one-to-one ratio, a wall defining the end of the screw chamber at the discharge ends of the screws, said wall provided within the axially projected outlines of one of the screws with an opening adapted to coact with the adjacent end of the screw facing the same to provide a valvular means for opening communication between the screw chamber and the discharge port once for each rotation of the screws, said opening being arc shape with its inner and outer edges concentric and each extending for not more than 220°, with one end defined by a short concaved curve and its other end by a short convex curve connecting said inner and outer edges and in which the thread of the screw which faces said opening is concaved on the side facing the opening.

7. In a screw pump, the combination of a pump casing, mechanism for propelling a fluid through the casing and for imposing a pressure thereon, said mechanism including a pair of rotors, each including a shaft and provided with a spiral thread, with the threads intermeshing, means for driving one rotor from the other, each thread being concave on one side and related with the concave side of one thread facing the concave side of the other thread, a barrier at the discharge end of the threads through which the two shafts loosely extend, and against which both threads abut, said barrier provided within the axially projected outline of that thread whose concave side faces the barrier with a discharge port, and said port outlined by at least three sides, one of which is convex and coincides with the axially projected outline of the perimeter of the other thread, another side of which is concave and extends inwardly from the casing towards the shaft which forms part of the discharge thread and whose third side is a circular arc concentric with said last named shaft.

8. The screw pump defined in claim 7 and in which the discharge port is of less area than the groove of the thread which discharges into the same, once for each rotation of the thread.

9. In a device of the class described, the combination of a pump casing, mechanism for moving a fluid through the casing and including a pair of rotors journalled in the casing and each provided with a spiral thread with the threads

in intermeshing relation, means for driving one rotor from the other, the thread of each rotor being concaved on one side and with the concave side of one thread facing the concave side of the other thread, means forming a barrier at the discharge end of the threads and against which the threads abut, said barrier in the portion thereof which faces the concave side of one of the screws provided with a discharge opening and said barrier being otherwise closed.

10. In a device of the class described, the combination of a pair of intermeshing helical rotors mounted to rotate about parallel axes and intergeared to drive one from the other, each rotor having an outer peripheral surface of cylindrical curvature, each rotor exhibiting in any section perpendicular to its axis a compound curved outline whose ends meet the outer cylindrical curvature with one outer portion of the curved outline concaved and the other outer portion convex and with the part connecting the concaved and convex portions forming an exposed part of a root-circle concentric with the axis of rotation of the associated rotor, and the convex portion between the root-circle and the cylindrical curvature being a plane, simple curve substantially that of a portion of an Archimedean spiral, a casing whose inner wall conforms to the paths of the outer cylindrical surfaces of said rotors, and power means for driving the rotors.

11. The device defined in claim 10 and wherein a wall closes the casing at one end of the rotors and against which wall both rotors abut, the wall in the portion thereof facing one of the rotors provided with a discharge opening located within the outlines of the axially projected cross section of said one rotor and located exteriorly of its projected root-circle, one edge of which opening coincides in one position of said one rotor which said convex portion of said one rotor, and said one rotor coacting with the opening to form a valve for regulating the discharge from the casing once for each rotation of said rotors.

12. In a positive displacement rotary type compressor, the combination of a pump casing open at opposite ends and provided at one end with a fluid intake port, a first closure for the casing at the end provided with said port, a second closure for the casing at its opposite end and provided with a discharge opening, said second closure being readily demountable from its end of the casing and fashioned to be replaced by a similar closure having a discharge opening of a different size, a pair of intermeshing screws fitted for free rotary movement in the casing and interconnected to drive one from the other, said screws having their ends journaled in the closures, each screw bearing at one end axially on said second closure and at its other end disposed in spaced relation to the first closure to form a space at the intake ends of the screws wide open to the fluid intake port, one of said screws constituting a discharge screw with the channel between its threads at its discharge end facing the discharge opening, said discharge opening having an arc length less than the arc length of the channel formed between the thread turns of the discharge screw and thus less than the discharge area of the discharge screw.

13. In a device of the class described, the combination of a pump casing, mechanism including a pair of intermeshing screws mounted for free rotary movement in the casing to advance a fluid axially through the casing, one of said screws forming a fluid discharge screw and one side of the thread of which discharge screw is convex in cross section through the screw, a closure for the casing at the discharge ends of the screws and against which both screws abut, said closure provided with a single discharge opening facing the adjacent end of the discharge screw and offset from its axis, and said closure otherwise closing the end of the casing at the discharge end of the screws, said opening being in the form of a curvilinear triangle whose area is materially less than the opening between the threads of the discharge screw at its discharge end and one side of which opening has a concaved curve substantially the same as the convex curve of the thread.

14. In a device of the class described, the combination of a pair of intermeshing helical screws of the same external diameter and pitch circle, mounted to rotate about parallel axes and intergeared to drive one from the other at a one-to-one ratio, each screw having an outer surface of cylindrical curvature defining its pitch-circle, each screw exhibiting in any section perpendicular to its axis a compound curve, with one outer portion concaved and the other outer portion convex and with the portions connecting the convex and concave portions forming a hub whose perimeter forms a root-circle concentric with the axis of rotation of the associated screw, a wall against which both rotors abut, the wall provided within the axially projected area of one of the screws with a discharge outlet coacting with said screw to form a valve open once for each rotation of the screws, said outlet exhibiting in a similar cross section perpendicular to the axis of said screw an arcuate form and whose inner outlining edge is concaved and coincides with a portion of the root-circle of said screw, and the outline of which discharge outlet is also defined by two curves with their inner ends circumferentially spaced apart on the root-circle and extending outwardly therefrom, one of said two curves being concaved and coinciding with a portion of the pitch circle of the other screw and the other of said two curves being convex and coinciding with the convex side of the associated screw, and a casing whose inner wall conforms to the paths of the outer cylindrical surfaces of the screws.

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