Dec. 6, 1966 J. E. WHITFIELD 3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Filed March 13, 1964 6 Sheets-Sheet 1

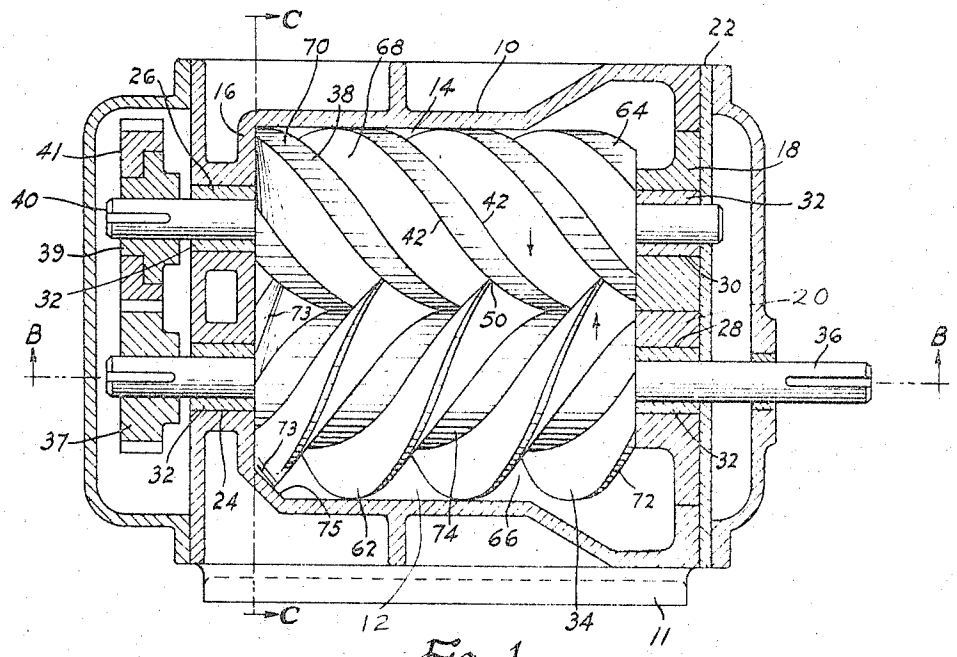


Fig. 1

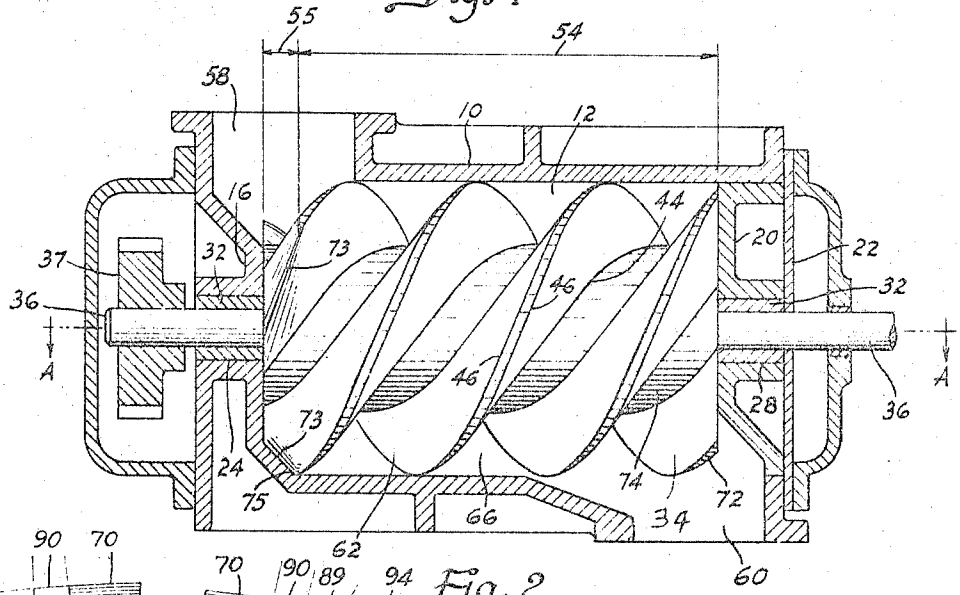


Fig. 2

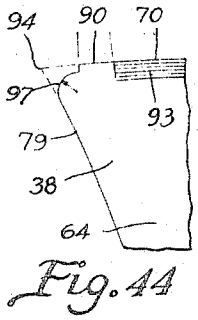


Fig. 44

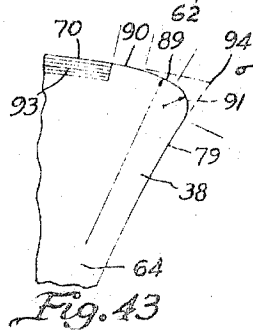


Fig. 43

INVENTOR.
JOSEPH E. WHITFIELD

BY
Cameron, Kerkam & Sutton

ATTORNEYS

Dec. 6, 1966 J. E. WHITFIELD 3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Filed March 13, 1964 6 Sheets-Sheet 3

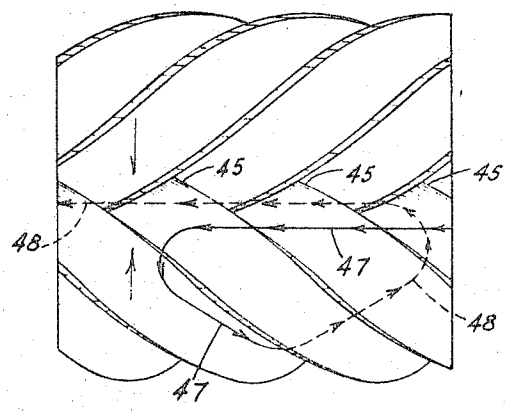


Fig. 6

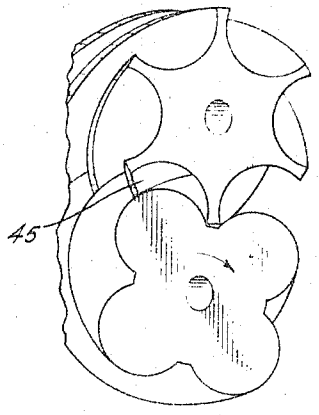


Fig. 5

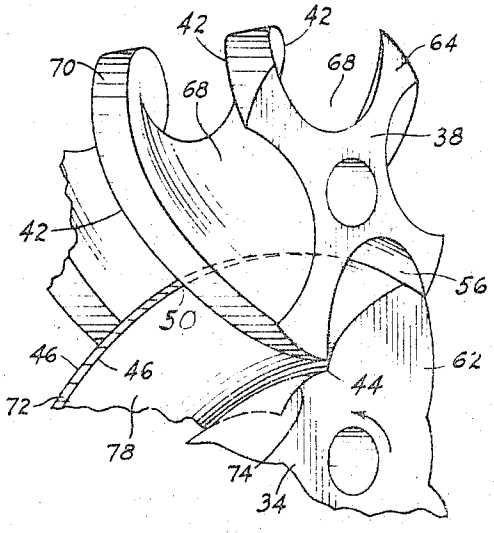


Fig. 4

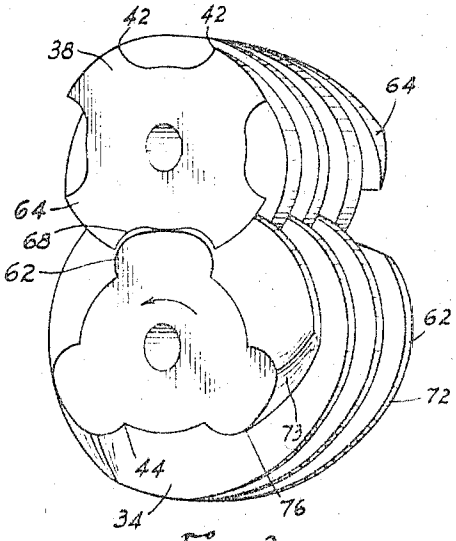


Fig. 3

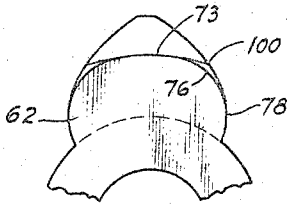


Fig. 42

INVENTOR.
JOSEPH E. WHITFIELD

BY
Cameron, Kerkam & Sutton

ATTORNEYS

Dec. 6, 1966 J. E. WHITFIELD 3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Filed March 13, 1964 6 Sheets-Sheet 3

Fig. 8
DISCHARGE END VIEW

76 GENERATING ARC
78 GENERATED SIDE, MAIN
79 GENERATED SIDE, GATE
81 GENERATED BY 73
83 GENERATED BY 76
84 PITCH CIRCLE, GATE
86 PITCH CIRCLE, MAIN

Fig. 7
DISCHARGE END VIEW

Fig. 10
SEC. B-B, FIG. 34

66 TROUGH, MAIN
68 TROUGH, GATE
70 LAND AT TIP, GATE
71 INCLINED TROUGH
72 LAND AT TIP, MAIN
73 INCLINED LAND
74 LAND AT ROOT, MAIN

Fig. 9
SEC. A-A, FIG. 33

Fig. 12
SUCTION END VIEW

34 MAIN ROTOR
38 GATE ROTOR
42 CREST EDGE, GATE
44 ROOT OF THREADS
46 CREST EDGE, MAIN
62 THREAD, MAIN
64 THREAD, GATE

Fig. 11
SUCTION END VIEW

INVENTOR.
JOSEPH E. WHITFIELD

BY
Cameron, Kirkham & Sutton

ATTORNEYS.

Dec. 6, 1966 J. E. WHITFIELD 3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Filed March 13, 1964 6 Sheets-Sheet 4

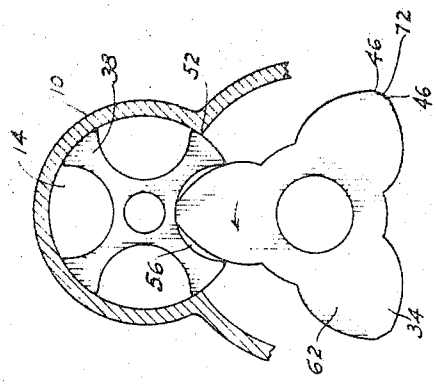
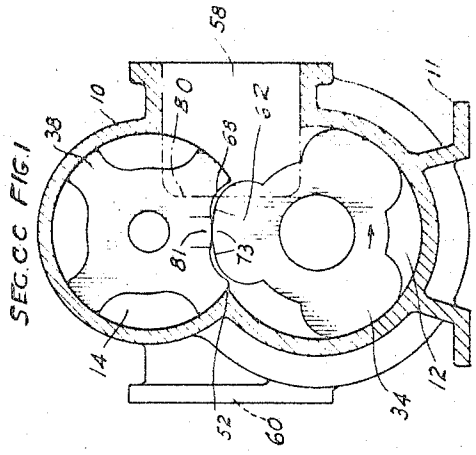


Fig. 20



SEC. CC FIG. 1

Fig. 16

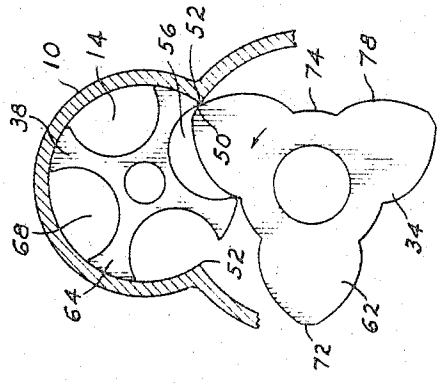


Fig. 19

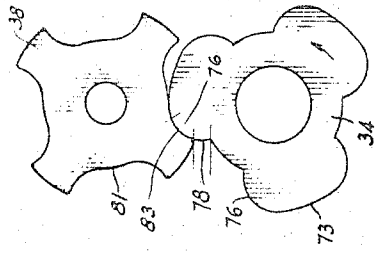


Fig. 15

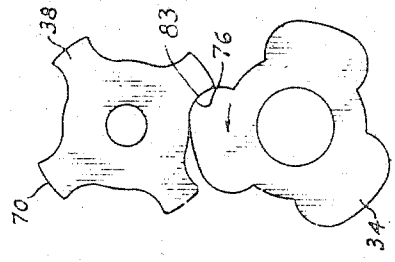


Fig. 18

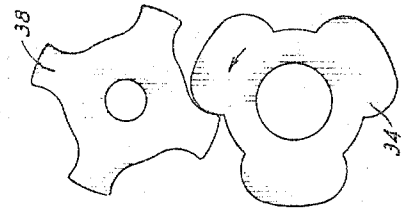


Fig. 14

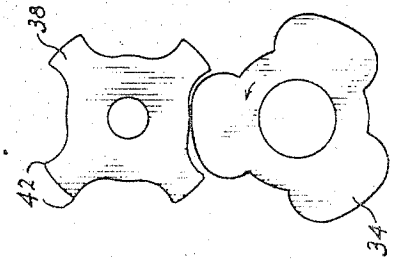


Fig. 17

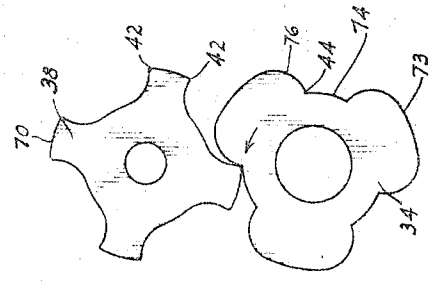


Fig. 13

INVENTOR.
JOSEPH E. WHITFIELD

BY Cameron, Kerkam & Sutton

ATTORNEYS

Dec. 6, 1966 J. E. WHITFIELD 3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Filed March 13, 1964 6 Sheets-Sheet 5

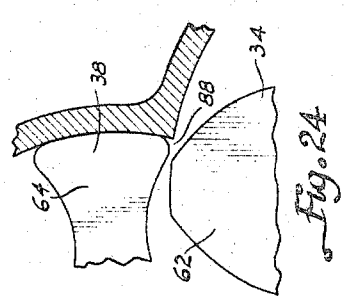


Fig. 24

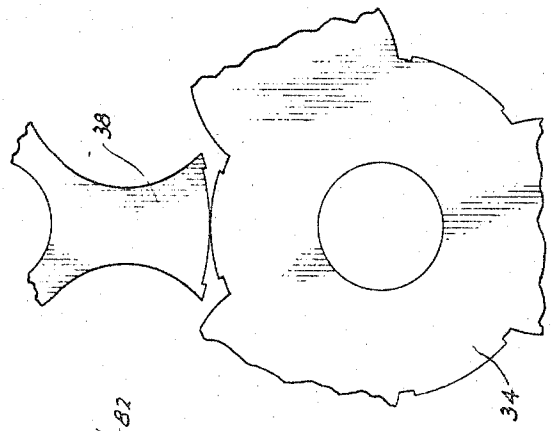


Fig. 23

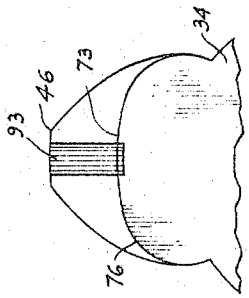


Fig. 26

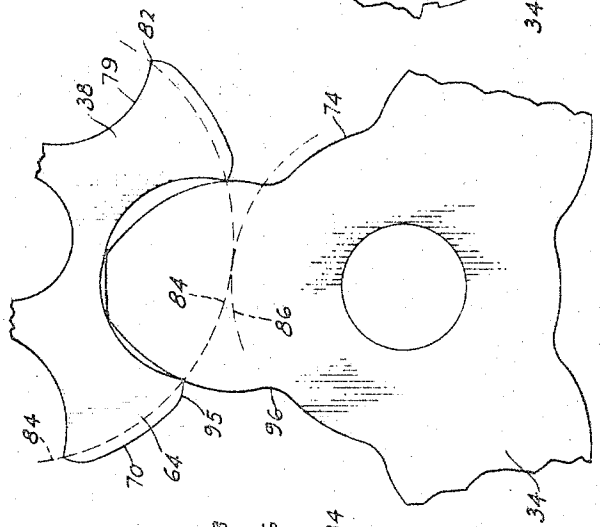


Fig. 22

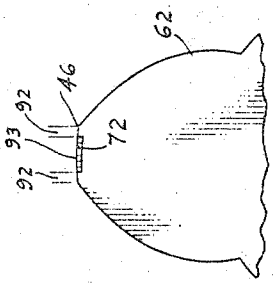


Fig. 25

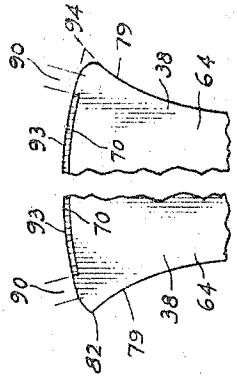


Fig. 27 Fig. 28

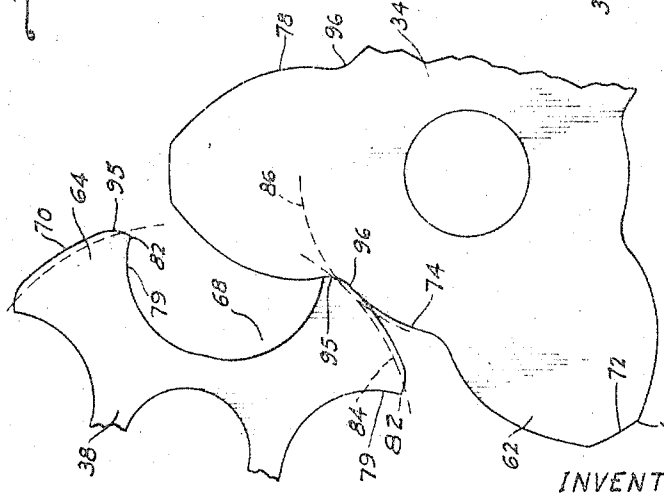


Fig. 21

INVENTOR.
JOSEPH E. WHITFIELD

BY
Cameron, Kerkam & Sutton

ATTORNEYS

Dec. 6, 1966 J. E. WHITFIELD 3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Filed March 13, 1964 6 Sheets-Sheet 6

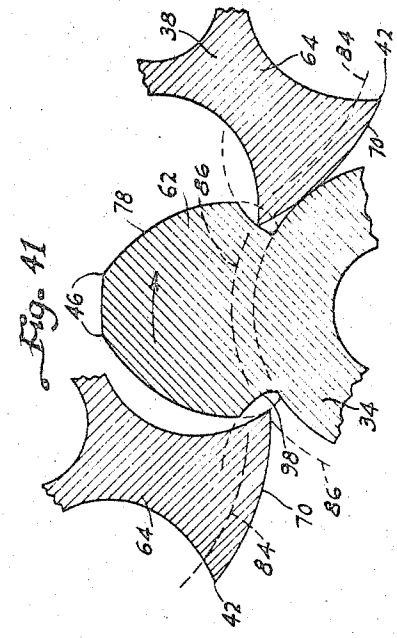


Fig. 41

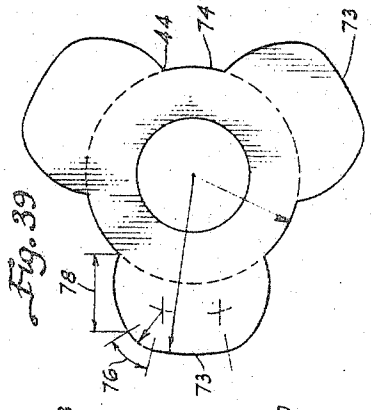


Fig. 39

SEC. A-A, FIG. 33

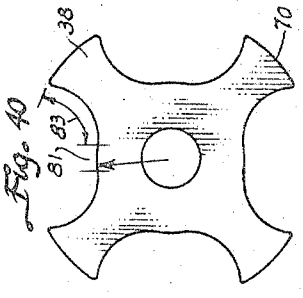


Fig. 40

SEC. B-B, FIG. 34

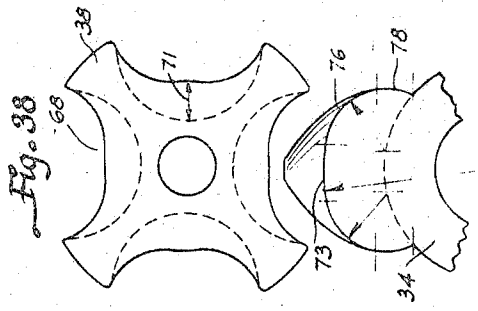


Fig. 38

Fig. 37

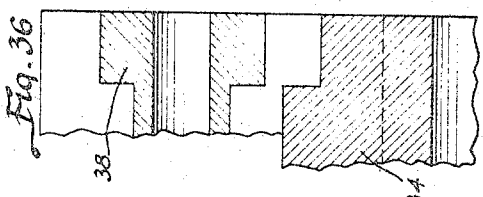


Fig. 36

Fig. 35

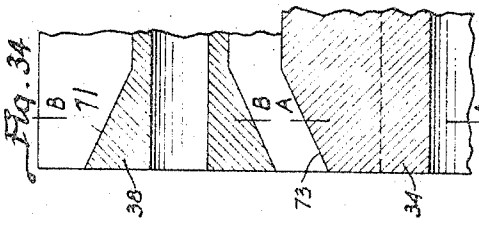


Fig. 34

Fig. 33

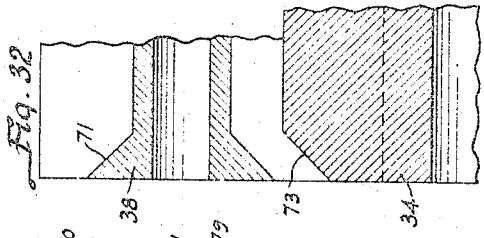


Fig. 32

Fig. 31

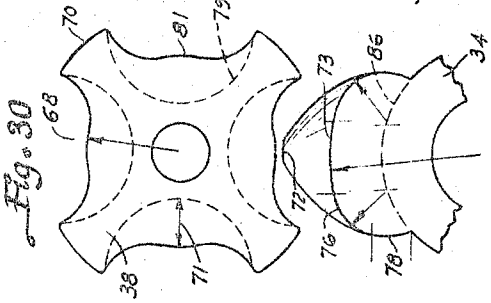


Fig. 30

Fig. 29

INVENTOR.
JOSEPH E. WHITFIELD

BY
Cameron, Kerkam & Sutton

ATTORNEYS

United States Patent Office

3,289,600
Patented Dec. 6, 1966

3,289,600

HELICALLY THREADED ROTORS FOR SCREW TYPE PUMPS, COMPRESSORS AND SIMILAR DEVICES

Joseph E. Whitfield, P.O. Box 325, York, Pa.

Filed Mar. 13, 1964, Ser. No. 351,766
18 Claims. (Cl. 103—128)

This invention relates generally to fluid pumps, motors, compressors, blowers, meters and similar devices in which interengaging rotary members are provided with helical intermeshing threads, and, more particularly, to the novel features of the rotary members, the housing in which they operate and other associated parts embodied with any one of these devices.

Screw type fluid motors, blowers and the like have two or more helically threaded rotor members rotatably supported in a housing with their axes parallel, for example, and with their complementary threads intermeshing to provide a continuous seal line the full length of the rotors. The housing encloses both or all of the rotary members and the perimetric tip of each thread on the rotary members forms a seal therewith. Thus any flow of fluid from the suction port at one end of the blower to the discharge port at the opposite end must pass through the spaces enclosed by the threads on the rotary members in cooperation with the housing.

The threads must be complementary to form satisfactory seals and pockets, and to permit rotation of the members. Thus one rotary member has right-hand threads while the mating rotary member has left-hand threads.

While more than two rotary members can be used, only two will be shown and described herein for purposes of simplicity. The threads on one of the rotors usually lie wholly, or almost wholly, outside its pitch circle. This rotor does most of the work of compression, and is termed the main rotor. The threads on the other rotor usually lie wholly, or almost wholly, within its pitch circle. This rotor does very little work of compression, but forms a valve or gate across the path of the main rotor, and is termed the gate rotor. The main rotor is sometimes called the male rotor and the gate rotor is sometimes called the female rotor, but it is preferred to designate them as the main and gate rotors.

When rotated, the main rotor threads, in effect, act as a continuous series of pistons which slide endwise through the troughs between the threads of the gate rotor and produce a continuous series of pockets which convey the fluid from the suction end of the rotors to the discharge end thereof. The opening in the intake end of the housing is termed the suction port and the opening in the outlet end is termed the discharge port. Axial flow screw type devices of this general construction are usually reversible, and such reversing reverses the functions of the ports, but this disclosure is directed to a device that is more efficient when operated in one certain direction and, in general, is not reversible.

This general type of device is old and well known in the art and is in use for various purposes. However, all such devices heretofore known have had certain very serious limitations. For instance, certain thread forms do not produce continuous seals between the rotors, or between the rotors and housing, and leakage results. Others have low capacity for a given bulk size, while still others have a rotor form in which the threads on one member are not rigid enough for the purpose, and several known thread forms are very difficult to machine accurately. The most serious fault with former rotor designs is their formation of sealed pockets at the discharge end which create excessive pressure, temperature and noise. However, certain basic advantages of the screw type devices are so desirable that they have been accepted,

to a considerable degree, despite their known inadequacies.

To produce a more ideal device of this type, it is necessary that the sealing line between the rotors themselves, and also between both rotors and the housing, remain unbroken during all periods of rotation as the rotors revolve; that the rotors and associated shafts be of rigid design; that the rotors be of such shape that they can be made accurately and economically; and that no sealed pockets be formed, and no leakage openings develop, as the rotors revolve. All these desirable objects may be accomplished with the new rotors disclosed herein.

The number of threads on each rotor is generally a matter of choice and depends upon speed, pressure and other considerations. A larger number of threads is generally chosen for extremely high speeds and high internal compression ratios. The other extreme would be two threads on the main rotor and three or four on the gate rotor. Any of these combinations will operate and all will have certain advantages over other combinations. However, it is believed that three threads on the main rotor and four threads on the gate rotor provide the best and most universal combination. This disclosure will therefore be directed to such a combination, but the invention is not limited thereto.

When accurately formed, the complementary threads of the rotor members will operate as smoothly as a set of gears, and the main rotor can be used to drive the gate rotor. However, since in actual use the rotors usually operate without lubrication on the thread surfaces, and because of the high speeds at which these devices operate, it is generally advisable to provide timing gears, and rotors with certain fixed clearances, so that the rotors operate in timed relation and do not contact each other or the housing. It has been found that, should the rotors contact each other or the housing, the friction between the parts will produce heat and cause failure unless very careful steps are taken to allow the parts to wear in without creating extreme heat or pressure. Thus, it is important to have rigid parts that can absorb considerable power without deflecting and making contact with other parts. Furthermore, as the rotors do not make contact with each other or with the housing, they are not subject to wear. The improved device of the present invention thus has two fundamental desirable features, i.e.; the rotors do not require lubrication, and they are not subject to wear under normal conditions.

The principal object of this invention is to provide rotors with arc generation and congruent sealing at the root of the main rotor threads.

A second important object of the invention is to eliminate the sealed pockets normally formed at the discharge end of the rotors just before the pockets run out.

Another object is to provide wide, unbroken, highly effective sealing lines.

Another object is to provide rotors that form pockets which run out to zero without loss in capacity.

Another object is to provide a device in which both rotors can be effectively cooled by liquid circulated therein.

Another object is to provide a gate rotor having threads that are well supported against deflection.

Another object is to provide a gate rotor that will accommodate a larger shaft than heretofore possible without reducing the diameter of the main rotor throughout its length.

Another object is to provide a main rotor with an inclined land at one end, and a complementary inclined portion at one end of the main rotor chamber of the housing.

Another important object is to provide such a device that is suitable for higher speeds and pressures than similar devices of the prior art.

Another object is to provide a blower wherein the discharge pockets run out as they approach the center line between the rotors.

Another object is to provide such a device wherein the extreme end of a suction pocket does not become interposed between the discharge pocket and the discharge port.

Another object is to provide rotors having tips that will wear away when making contact with the housing without creating mechanical trouble and still maintain normal clearance.

Another object is to provide rotors having wide sealing lines in the high pressure area.

Another object is to provide rotors having all the above advantages with threads of completely generated form.

Another object is to provide rotors having wear strips on the tips of the rotor threads and a sealing material between the wear strips to prevent leakage.

Another object is to provide intermeshing helically threaded rotors that discharge all the air taken into the suction pockets thereof, there being no clearance spaces and/or no re-expansion spaces.

Other objects and advantages will appear from the following description, reference being had to the several embodiments illustrated in the accompanying drawings in which:

FIG. 1 is a longitudinal sectional view of one form of screw type pump or compressor embodying the present invention, the section being taken through the axes of the rotor members on line A—A of FIG. 2.

FIG. 2 is a longitudinal sectional view taken through the axis of the main rotor on line B—B of FIG. 1, perpendicular to the view in FIG. 1, and showing the suction and discharge ports.

FIG. 3 is a perspective view of a pair of rotors per se embodying the invention.

FIG. 4 is a fragmentary perspective end view of a pair of prior art generated rotors showing the formation of a sealed pocket at the discharge end, the end wall which completes the sealing of the pocket not being shown.

FIG. 5 is a fragmentary perspective end view of a pair of prior art rotors with arcuate threads almost in full mesh, showing that there are no sealed pockets at the discharge end. The normal end wall, not shown, would not seal these pockets.

FIG. 6 is a side view of a pair of meshed rotors having arcuate threads throughout their length, as in FIG. 5, showing openings and a leakage path at the point of intersection of the threads.

FIGS. 7 to 12, inclusive, are diagrams of rotor sections according to the invention comprising what may be termed a nomenclature sheet, the preferred names, together with the reference numbers, of the various parts of the rotors being given as they are used throughout the specification and claims. FIGS. 7 and 8 illustrate the discharge ends of the main and gate rotors, respectively; FIGS. 9 and 10 represent sections through the non-uniform discharge portions of the main rotor and the gate rotor, respectively, taken on line A—A of FIG. 33 and line B—B of FIG. 34, FIG. 10 being complementary to FIG. 9; and FIGS. 11 and 12 illustrate the suction ends of the main and gate rotors, respectively.

FIGS. 13, 14 and 15 are diagrams illustrating the positions of the discharge ends only of the rotors when the rotors are approximately 40 degrees, 30 degrees and 12 degrees, respectively, before full mesh.

FIG. 16 shows the discharge ends of the rotors in full mesh, and includes a transverse section of the housing taken on line C—C of FIG. 1.

FIGS. 17 and 18 are diagrams illustrating the positions of the discharge ends only of the rotors when the rotors are approximately 6 degrees and 12 degrees, respectively, past full mesh.

FIGS. 19 and 20 are transverse sections through the uniform generated portions of the rotors when the rotors are approximately 32 degrees before full mesh, and in full mesh, respectively, also showing a fragmentary portion of the housing.

FIG. 21 is a fragmentary transverse section of a pair of rotors taken through the uniform generated section, the crest edges of the gate rotor being rounded with the rounded edges being centered on the pitch circle.

FIG. 22 is a fragmentary transverse section of a pair of rotors taken through the uniform section, the crest edges of the gate rotor being rounded with the rounded edges being wholly outside the pitch circle.

FIG. 23 is a fragmentary transverse section of a pair of rotors taken through the uniform section, the land at the tip of the gate rotor being cut away to form wearing strips along the crest edges and the main rotor hub being complementary.

FIG. 24 illustrates the leakage opening formed at the intersection of the housing chambers when the crest edges of the gate rotor are broken in any manner.

FIG. 25 illustrates the tip of a main rotor thread having a wearing strip along each of its crest edges and a softer sealing material filling the space between the wearing strips.

FIG. 26 shows the softer sealing material continued through the inclined land of the main rotor.

FIG. 27 is an enlarged view of one of the crest edges of the gate rotor thread shown in FIG. 22 showing a sharp intersection for point generation and a narrow wear strip.

FIG. 28 is an enlarged view of one of the crest edges of a gate rotor thread having a rounded intersection for arc generation and a narrow wear strip.

FIGS. 29 to 38, inclusive, are fragmentary views of various forms of rotors, each pair of rotors being slightly separated and shown untwisted for clarity. FIGS. 29 and 30 show the discharge end of a main rotor thread and a gate rotor thread, respectively, the inclined land of the main rotor extending from the tip of the thread to one-half the height of the thread, while the inclined trough section of the gate rotor extends from the bottom of the trough outwardly to one-half the depth of the trough. FIGS. 31 and 32 are fragmentary longitudinal sections through a main rotor thread and a gate rotor thread, respectively, at the discharge end thereof, the angles of the inclined land of the main rotor and the inclined trough section of the gate rotor being relatively steep. FIGS. 33 and 34 are similar to FIGS. 31 and 32 except that the angles of the inclined land and trough section are relatively gentle. FIGS. 35 and 36 are similar to FIGS. 31 and 32 except that the change in shape of the main and gate rotor threads is abrupt, there being no inclined land or inclined trough section. FIG. 37 shows the discharge end of a main rotor thread wherein the inclined land extends from the tip of the thread to less than one-half the height of the thread, while FIG. 38 shows the discharge end of a gate rotor complementary to the main rotor of FIG. 37.

FIGS. 39 and 40 are diagrams of transverse sections of the main rotor and the gate rotor of FIGS. 33 and 34, respectively, taken on line A—A of FIG. 33 and line B—B of FIG. 34.

FIG. 41 is a diagram of the threads of a pair of rotors wherein the main rotor hub is smaller than its pitch circle and the outside diameter of the gate rotor is larger than its pitch circle, the gate rotor thread having sharp crest edges and being indicated at two different positions relative to the main rotor thread.

FIG. 42 is a fragmentary end view of a main rotor thread showing the amount of metal to be removed, after the inclined land has been cut, in order to produce generating arcs which generate the gate rotor troughs.

FIG. 43 is a fragmentary enlarged view of the crest edge of the gate rotor shown in FIG. 28 wherein the two-arc form of the rounded crest is more clearly indicated.

FIG. 44 is a fragmentary enlarged view of another form of arcuate crest edge for the gate rotor.

It is important to note that the drawings are accurate scale representations, many traced from templates of rotors embodying the invention, particularly as respects the sectional outline diagrams of the rotor threads. Accordingly, in the interest of accuracy, shade lines have been omitted from many of the figures and diagrams.

In the specification and claims certain terms such as "troughs," "pockets," "run out," "timing gears" and "timing" are used, and to render the meanings thereof clear, the following definitions are set forth.

Troughs.—The grooves or spaces between the threads on either rotor may be termed troughs, and are similar to the spaces between the teeth on common gears. The side surfaces of the troughs may also be termed the flanks or sides of the rotor threads.

Pockets.—The merging together of a trough on each rotor together with the housing chamber walls form a pocket, it being the pockets that convey the fluid from the suction end to the discharge end of the rotors.

Run-out.—This is the term used in connection with the pockets or troughs as they reach the discharge end of the rotors and decrease in size to zero, i.e., vanish or "run out." At the suction end of the rotors the pockets form and continue to fill with fluid until they reach maximum size as the rotors revolve. They are then disconnected from the suction port and begin to decrease in size and compress the fluid therein. Compression continues until the edge of the discharge port is reached when discharge of the fluid takes place. After passing the edge of the discharge port, sealed pockets no longer exist, but the troughs continue to advance to the discharge end where they vanish or "run out."

Timing gears.—Gears are used to synchronize the rotors and keep them in timed relation. The clearance between the rotor threads must be greater than the clearance between the gear teeth if contact between the rotors is to be avoided in operation. The clearance between the gear teeth may be .002" to .004" while the clearance between the rotor threads may be .020" to .040", depending upon the size of the device. Thus, if timed properly, the rotor threads cannot make contact with each other as they are held in spaced relation by the timing gears.

Timing.—Timing is the act of setting the timing gears in relation to the rotor threads to eliminate contact between said threads. One of the timing gears is usually made separately from its hub and is adjustable with respect thereto to facilitate the timing operation when the device is assembled.

Referring now to FIGS. 1 and 2, wherein the invention is shown, by way of example, as applied to a screw type pump or compressor, the housing **10** of the device contains two parallel cylindrical chambers **12** and **14** disposed side by side in parallelism and merging into each other to form a common chamber, the cross section of which is somewhat in the form of a figure **8**. The housing is provided with supporting feet **11** and with an integral end wall **16** which forms one end wall of the chambers **12** and **14**. The other end of the housing is formed by a removable end wall to enable insertion of a pair of mating helical screw thread rotor members **34** and **38** which are arranged to operate within rotor chambers **12** and **14**, respectively. Rotor **34** is termed the main rotor, and has left-hand threads in the embodiment illustrated. Rotor **38** is termed the gate rotor and has threads which are complementary to those of the main rotor, i.e., right-hand.

The removable end wall of the housing is made in two parts in the form of re-entrant heads which are self centering. The re-entrant head **18** for the gate rotor chamber **14** is continuously circular on its outside diameter and fits the chamber without clearance. The re-entrant head **20** for the main rotor chamber **12** is also circular on its outside diameter except it has a concave niche formed in one side to allow it to be assembled into the housing beside the gate rotor re-entrant head. The re-entrant heads **18** and **20** are held in proper relation to the housing by the headplate **22**. The housing end wall **16** is provided with two cylindrical bearing bores **24** and **26** which are concentric with the main rotor chamber **12** and the gate rotor chamber **14**, respectively. Likewise, the re-entrant heads **18** and **20** are provided with cylindrical bearing bores **30** and **28**, respectively, which are centrally located in their respective re-entrant heads.

Each of cylindrical bearing bores **24**, **26**, **28** and **30** is provided with a bearing bushing **32**, which may be similar for all bearings. The main rotor **34** is fixedly attached to a shaft **36** and is centrally located in the main rotor chamber **12** by the bushings **32** in bearing bores **24** and **28**. The gate rotor **38** is likewise fixedly attached to a shaft **40** and is centrally located in the gate rotor chamber **14** by the bushings **32** in bearing bores **26** and **30**.

The main rotor shaft **36** has a timing gear **37** fixedly attached thereto while the gate rotor shaft **40** has a hub **39** fixedly attached thereto on which the gate rotor gear **41** is adjustably mounted in any known manner. This provision for adjustment allows the rotor threads to be timed in spaced relationship.

There is a lateral discharge port **58** in the gear end of the housing and a lateral suction port **60**, diagonally opposite, in the drive end of the housing. The shapes and sizes of these ports will be described later.

The rotor chambers **12** and **14** and the re-entrant heads **20** and **18** are slightly larger in diameter than the rotors **34** and **38** to insure that the rotors are centrally located in a positive manner and may operate with a minimum clearance. Common bearing bushings **32** are shown for reasons of simplicity, but it will be understood that suitable bearings may be supplied to carry both the radial and the thrust loads which are developed in such a device.

The main rotor **34**, as shown, has three circumferentially extending, axially evenly spaced helical threads **62** of identical contour, the exact shape of which is described hereinafter. The gate rotor **38**, as shown, has four circumferentially extending, axially evenly spaced helical threads **64**, the exact shape of which is also described later. The principal object of this invention being to provide theoretically perfect sealing, and to eliminate sealed pockets at the discharge end of the rotors, that part of the invention, i.e., the rotors, will be described first with particular reference to FIGS. 1, 2, 3, 4, 16 and 19.

In devices of this type, what may be termed "theoretically perfect sealing" is actually a close running seal with fixed predetermined clearance. That is, the clearance between the rotor threads themselves and between the tips of the rotors and the housing chamber walls is established during manufacture of the device and does not change under normal operating conditions beyond a predetermined permissible amount. This built-in clearance may be termed "space packing" or "close running clearance." With rotors having correct design and accurately machined threads the running clearance may be at a minimum and will be substantially equal throughout the confining edges of the pockets during all periods of rotation.

In the generated rotors of FIG. 4, the crest edges **42** of the gate rotor **38** are shown as forming an unbroken seal from the root **44** of the thread of the main rotor to its crest edge **46**. Likewise, the crest edges **46** of the main rotor **34** form an unbroken seal across the trough **68** of the gate rotor. Thus there is no opening between the rotor threads at the point where the crest edges **42** and **46** of the rotors meet to form the intersection **50** (FIGS. 4 and 19). Together with the housing chambers intersection **52** (FIGS. 19 and 20), the rotor threads and the housing chamber walls form a theoretically perfect seal and the fluid being pumped is sealed against leakage from the forward high pressure pockets to the trailing low pressure pockets.

With the new rotors disclosed herein, the seal **50** at **52** (FIG. 19) exists throughout the uniform generated section **54** (FIG. 2). This type of sealing is highly desirable in

the compression area and forms a very important part of this invention. This theoretically perfect seal forms at the suction end of the rotors and advances with the pockets to the discharge port as the rotors revolve. Since there are no leakage openings between the forward high pressure pockets and the trailing low pressure pockets, true adiabatic internal compression is attained, which is highly desirable for good efficiency.

FIGS. 5 and 6 show rotors having arcuate threads throughout their length. Such rotors are disclosed in Nilsson Patent No. 2,622,787. It will be noticed that these arcuate rotors of FIG. 5 do not intersect as the threads enter into mesh as do the generated rotors at 50, FIG. 4. Consequently, a leakage path 45 is created extending continuously from the discharge end to the suction end which eliminates true adiabatic compression. The solid line arrows 47 in FIG. 6 show this leakage path on the forward side of the rotors. Also, as shown, should the rotors have more than a certain amount of wrap angle, then the leakage can follow a trough around the rotor, after which it will be in a position to leak directly to the suction port. The obscure leakage path is indicated by the broken line arrows 48 in FIG. 6. Thus, such rotors have a direct leakage path built into them. If these arcuate thread rotors are built with a small wrap angle to eliminate this direct leakage path, they cannot then produce a high ratio of internal compression. However, regardless of how low the wrap angle, there is always a leakage from a high pressure pocket to the trailing pockets as shown by the arrows 47.

As can be seen in FIG. 5, the form of these arcuate threads is such that they do not form sealed pockets at the discharge end, which, of course, is an advantage. However, with this design, the same opening 45 that vents the pockets at the discharge end also creates the leakage path from the discharge end to the suction end. Although the leakage loss can be reduced by excessively high speed operation, this is also a disadvantage. This leakage opening is fully described in the Nilsson Patent No. 2,622,787, column 12, where it is mentioned that high pressure fluid can leak back to the trailing pocket. However, Nilsson does not mentioned that leakage can, and does, occur directly between the discharge and suction ports, as shown by the solid and broken line arrows 47 and 48 in FIG. 6 herein, when the wrap angle is great enough to produce high internal compression as is necessary in most devices of this nature. This is a very serious limitation where high efficiency is essential.

In FIG. 6, with the rotors operating as indicated by the opposing arrows, the discharge port would be on the front side at the right-hand end while the suction port would be on the rear side at the left end. The solid line arrows 47 show the leakage path across the front side and half way around the main rotor while the broken line arrows 48 show the leakage path on the obscure and rear side of the rotors. A leakage path is thus traced continuously from the discharge port to the suction port, resulting in a loss in efficiency which the present invention eliminates.

The original Whitfield blower of Patent No. 2,287,716 was developed to eliminate the leakage path developed by arcuate threads. As shown in FIG. 19 herein, with generated threads there is no leakage opening formed at the intersection 52 of the housing chambers, which is highly desirable in the compression area. However, since fully generated rotors have no natural vent or leakage opening, they form a sealed pocket 56 (FIG. 4) at the discharge end, which is a serious disadvantage. As mentioned above, the end wall which completes the sealed pocket is not shown in FIG. 4.

The new rotors provided by the present invention are intended to eliminate the faults of the arcuate rotor threads as developed by Nilsson, and the faults of the generated rotor threads as developed by Whitfield, while retaining the advantages of both designs.

The rotors shown in Whitfield Patent No. 2,922,377 eliminate the sealed pocket formed by generated threads, and also eliminate the leakage path formed by arcuate threads, but they have been found to be difficult to produce accurately and their design reduces the capacity of the unit. There is a true rolling motion between these rotors at the discharge end; that is, one cone rolls on the other at substantially the same peripheral speed. Thus a cutter made in the form of either rotor will not cut the mating rotor as there is only a rolling contact between the rotor and cutter.

As shown in the Whitfield Patent No. 2,792,763, to generate either rotor by rolling a rotor and cutter together in timed relation, there must be a relative motion, or difference in peripheral speed, between the cutter and the surface of the rotor being cut.

The fact that the threads on the rotors disclosed herein can be fully generated by rolling a rotor and suitable cutter together in timed relation to produce a theoretically perfect form is a very important improvement. It has also been found that the sharp sealing edges disclosed in Patent No. 2,922,377 provide an unsatisfactory sealing condition, and that the lengths of the sealing lines are longer than necessary. In the rotors of this disclosure, the sealing lines are shorter, have greater width and are much more effective.

In a copending Whitfield application, Serial No. 200,242, filed June 5, 1962, now Patent No. 3,138,110, dated June 23, 1964, another rotor form is disclosed which also eliminates the sealed pockets 56 and the leakage openings 45, mentioned above. However the relief vent in this disclosure is full size only at the extreme end of the rotors and decreases in width to zero at the intersection between the generated portion and the arcuate portion. Thus it is too small to fully vent the pockets at extremely high speed. Also, the main rotor and gate rotor in this application cannot be fully generated and the discharge areas of both rotors would be formed by a duplicating process from a master rotor, or template. Such a method of manufacture introduces inaccuracies and is slow and expensive when compared to rotary generation.

The rotor design shown in the present disclosure is a major improvement in simplicity of extremely accurate manufacture, and has higher speed possibilities and greater efficiency than those of prior designs.

With rotors having arcuate threads, such as those shown in Nilsson Patent No. 2,622,787, the opening that vents the pockets is the same size opening that exists at all the thread intersections back to the suction end. Consequently, if the thread is formed to provide a large vent opening at the discharge end, then the leakage openings to the trailing pockets will also be large and the leakage will be excessive.

In order to vent the pockets at the discharge end and not at the same time create a leakage path, the present invention provides rotors wherein the compression section is of different form from the discharge section, each section of the rotors being designed for its own specific purpose. The rotors disclosed herein are also of a form that is easily generated and controllable as to exact size and shape, and constitute a balanced design which is a major improvement over previous disclosures.

Again referring to FIG. 1, the rotors operate in the directions shown by the arrows, the suction port 60 being at the drive end on the far side while the discharge port 58 is diagonally opposite at the gear end on the near side, as indicated in FIG. 2. Since both rotors are fully generated from the suction end through the uniform section 54 to the non-uniform section 55, there are no leakage openings at the intersections 50 of the rotor threads and the intersection 52 of the housing chambers (FIG. 19).

FIG. 3 is a perspective view of the rotors only, shown in mesh and looking against the discharge end. The difference in form between the discharge and the com-

pression or generated portions of the rotors can be seen by comparing FIGS. 3 and 4. It will be noted from FIG. 3 that, when the rotor threads are in full mesh as shown, the main rotor thread 62 does not completely fill the trough 68 of the gate rotor 38, and there is a seal only at the center of the main rotor thread, the gate rotor trough 68 being wider than the thread 62. This condition is caused by the location of the pitch circles in relation to the rotor threads, as will be explained later in detail.

FIGS. 7 and 8 are diagrammatic end views of the discharge ends of the main rotor 34 and the gate rotor 38, respectively, and include the names of the various parts. FIGS. 9 and 10 are similar diagrammatic sectional views of the two rotors, the sections being taken on line A—A of FIG. 33 and line B—B of FIG. 34, while FIGS. 11 and 12 are diagrammatic end views of the suction ends of the rotors showing the form of the generated portions of the threads.

FIG. 13 shows the discharge ends of the rotors as the threads roll into mesh, the seal being along the crest edge 42 of the gate rotor thread and at the root 44 of the thread of the main rotor. The discharge of the fluid from the trough of the gate rotor is not restricted in any manner. FIG. 14 is a view similar to FIG. 13, except that the rotors have been rotated about 10 degrees toward full mesh. The seal is still on the crest edge of the gate rotor thread, but is slightly away from the root of the thread on the main rotor. There is still no closed pocket. In FIG. 15 the rotors have advanced another 18 degrees and are about 12 degrees before full mesh, at which time the generating arc 76 of the main rotor thread is congruent with an arcuate portion 83 of the gate rotor trough 68, providing an excellent seal. The discharge passage for the fluid is still open, and there is no entrapment. In order to provide a congruency between the generating arc 76 on the main rotor thread and the arcuate side 83 of the trough of the gate rotor as shown in FIG. 15, it is necessary that the points of radius, i.e., the centers of curvature, of the two arcs be coincident. Since the pitch circles of the two rotors are not tangent where the points of radius of the arcs 76 and 83 must be located, the points of radius for both rotors cannot be on the pitch circles of both rotors. For example, in FIG. 15, the point of radius for both rotors could be located on the main rotor pitch circle when the rotors are located in the exact position shown. Thus the point of radius for the gate rotor would be slightly outside its pitch circle.

FIG. 16 shows the extreme ends of the rotors at the discharge end of the pump with the housing in section on line C—C of FIG. 1. Here the main rotor thread 62 is in full mesh and still no entrapment occurs because the seal is in the center of the main rotor thread and the gate rotor trough 68 does not fit congruently. The phantom line 80 represents the edge of the discharge port 58 in the housing end wall 16 (FIG. 2). Those portions of the ends of the rotors to the left of line 80 are covered by the end wall 16, while the portions to the right of line 80 are not covered. Since the latter area is part of the discharge port 58, partial axial flow is provided.

In FIG. 17 the rotors are shown about 6 degrees past full mesh position and there is still no entrapment. At this position the remaining pocket is very small and vanishes completely with a further rotation of 6 degrees as shown in FIG. 18. In FIG. 18 a portion 76 of the thread of the main rotor is congruent with a portion 83 of the gate rotor trough, but on the opposite side from that shown in FIG. 15. It should be noted that the threads on both these rotors are completely generated even though there is a uniform and non-uniform section.

For example, the outside diameter of the gate rotor and the lands at the root of the main rotor threads are finished first in any suitable manner. These surfaces cannot be generated since there is no relative sliding motion between them when rotated together. After these surfaces are finished either rotor can be completely generated by rolling it together with a cutter having the form of the mating rotor and in timed relation. The rotors could be rough machined slightly oversize and then generated to exact size and shape as a finish operation. Compensation for cutter wear is achieved by slightly changing the timing between the cutter and rotor. Such a method of finishing the rotors will produce a theoretically perfect set of rotors as such cutters produce generated forms, controlled by the timing gears, and is not dependent on the accuracy of formed cutters.

In FIG. 19 the generated portions of the rotors are in about the same position as the ends of the rotors shown in FIG. 14. If FIG. 19 were to represent the discharge end of the rotors, 56 would be a sealed pocket like that shown in FIG. 4. In FIG. 20 the rotors have revolved about 30 degrees from the position shown in FIG. 19, and are in full mesh. The sealed pocket 56 has been reduced in size but still exists. A portion of the housing 10 is shown in FIGS. 19 and 20 to illustrate the housing chambers intersection 52.

FIG. 21 shows a modified pair of rotor sections in which the pitch circle 84 of the gate rotor 38 is smaller than its outside diameter while the pitch circle 86 of the main rotor 34 is larger than the diameter of its hub. Each crest edge of the gate rotor threads (cf. 42 in FIG. 12) is broken away by a radius which forms an arc 95, one end of the arc being tangent to the outside circumference of the rotor while the opposite end of the arc is not tangent to the side 79 of rotor trough 68, but instead intersects therewith to form a sharp edge 82 which provides for what is generally termed point generation. The hub of the main rotor has a fillet 96 at the root of each thread that is complementary to the arc 95 on the gate rotor thread and operates congruently therewith at certain periods of each revolution as shown in FIG. 21. In the embodiment of FIG. 21 the pitch circle 84 of the gate rotor is about midway between the outside circumference of the rotor and the generating edges 82.

FIG. 22 shows a pair of rotor sections similar to those of FIG. 21 except that the pitch circle 84 of the gate rotor passes through the generating edges 82 and the main rotor hub is complementary.

The generating edges 82 or crest edges 42 may lie inside the pitch circle 84 of the gate rotor, but must not lie outside thereof or a leakage opening will be developed as shown in FIG. 41 wherein the crest edges 42 are outside the pitch circle 84. When these crest edges describe the sides of the main rotor threads they break sealing engagement near the root of the main rotor threads during certain periods of each revolution and form leakage openings as indicated at 98. By rounding the corners of the gate rotor threads to the pitch circle, as shown in FIG. 22, this undercut can be avoided. However, rounded crest edges form a leakage path 88 as shown in FIG. 24, which leakage path is similar to but smaller than the one created by the arcuate threads of FIGS. 5 and 6.

The lands 70 of the gate rotor threads are preferably of the uniform width throughout the length of the rotor. Also, there is no change in the crest edges 42 or in the generating edges 82 throughout the length of the rotor. Likewise the lands 74 at the root of the threads of the main rotor are of the same width and shape throughout its length. While the lands on both rotors could be made differently through the non-uniform section 55 (FIG. 2), for reasons of simplicity in manufacture it is preferred that these lands do not change throughout the length of the rotors. On the other hand, the lands 72 at the tips of the main rotor threads are the same only through the uniform generated section 54 and then change continuously through the non-uniform section 55 to form the inclined lands 73. It should be apparent from the drawings that the rotors are symmetrical in cross section throughout their length.

From experience it has been found that the wide lands 70 of the gate rotor will not wear away when they make rubbing contact with the housing if their width and area are not reduced in some manner. However, such reduction of rubbing area must not produce a new leakage path that is larger than can be tolerated for good efficiency. In FIGS. 27 and 28 the center of the gate rotor land 70 is cut away to a relatively shallow depth leaving a narrow wear strip 90 near each crest edge of the rotor thread. If this wear strip 90 is to wear away properly and without difficulty, it is necessary that it be relatively narrow and low and supported away from the crest edge of the rotor so that, as heat is developed during contact with the housing at high speed, the heat that is generated can travel into the main part of the rotor and be dissipated without causing the rotor to suddenly expand and wear away too much material or stall the unit. Since it is advantageous to locate the wear strips 90 away from the crest edges of the rotor threads, the crest edges must be modified in some manner to attain this result. Such modification must produce the absolute minimum opening 88 (FIG. 24), and also must produce the optimum shape for the main rotor fillet 96 (FIGS. 21 and 22). The design shown in FIGS. 27 and 28 produce all these desired results, while the complementary fillet 96 at the root of the main rotor thread greatly strengthens the thread against fatigue breakage due to an abrupt change in section.

The structures shown in FIGS. 27 and 28 are alike except that in FIG. 28, which illustrates the preferred form, the generating edge 82 is rounded instead of sharp, thus producing arc generation on the main rotor threads. The formation of these generating edges is very important and forms an important part of this invention. It is highly desirable to move the wear strips 90 away from the crest edges of the threads without creating an undesirably large opening 88 (FIG. 24). This can best be done with a relatively large radius that is tangent with the land 70 and not tangent with the generated side 79 of trough 68. This produces a sharp edge 82 as shown in FIG. 27. In FIG. 28 this sharp edge is broken by a relatively small radius which provides a better seal. Thus the edge of the thread in FIG. 28 is made up of two arcs of different radii. As will be seen more clearly in the enlarged view of FIG. 43, the arc 89 of larger radius is tangent with the land 70 only, while the arc 91 of smaller radius is tangent with both the arc 89 and the generated side 79 of the trough 68. This rounded generating edge produces a better seal, and its exact size is easier to control and maintain, than a sharp edge. The point 94 in FIG. 28 represents the crest edge of the rotor thread before it is modified. Thus it can be seen that very little metal need be removed to produce these desirable results, and that the leakage opening 88 is of minimum size.

Another form of rounded or arcuate generating edge for the gate rotor is shown in FIG. 44. In this modification, the crest edge 94 of the rotor thread is cut away perpendicularly to the land 70 to form a well-defined outer edge of the wear strip 90, and the generating edge is formed by an arc 97 of small radius, one end of which is tangent with the generated side 79 of the trough 68 while the other end terminates at the root of wear strip 90.

FIG. 25 shows the wear strip improvement as applied to the main rotor. The center of the rotor land 72 is cut away to form a relatively shallow groove and to provide a narrow wear strip 92 adjacent each crest edge 46. Due to the shape of the main rotor thread, these wear strips are well supported and any heat produced by friction is easily dissipated into the rotor proper.

The shallow grooves in the lands 70 and 72 of the gate and main rotor threads are filled with a suitable material 93 that will provide a seal and also wear away if rubbing contact is made with the housing. The sealing material 93 is selected according to the fluid being pumped, but should be soft enough to wear away easily, just the required amount without melting, upon rubbing contact with the housing. Should the shallow groove in the gate rotor threads not be filled, a leakage would result as can be visualized from FIG. 23. The rotors being helical, any leakage endwise because of the grooves would be a direct leakage from the pressure side to the suction side of the pump.

FIG. 23 shows a method of eliminating the sealing material 93 in the grooves of the gate rotor threads, i.e., by grooving the hub of the main rotor to be complementary to the wear strips on the gate rotor. However, the constructions shown in FIGS. 27, 28, 43 and 44 are considered preferable to the design shown in FIG. 23 because the latter is difficult to produce and there is no support for the sealing strips on the gate rotor.

FIG. 26 shows a main rotor thread wherein the sealing material 93 is continued through the inclined land portion 73 to the discharge end of the rotor.

The location and size of the wear strips 90 and 92, and the form, size and shape of the modified crest edges on the gate rotor, form an important part of this invention.

FIG. 29 is an end view of the discharge end of a main rotor thread embodying the invention wherein the inclined land 73 slopes downwardly from the land 72 at the tip to a point at which its height is about one-half the height of the uniform portion of the thread. As will be seen best in FIG. 2, the length of the inclined lands 73 is less than the normal axial dimension of the discharge port 58. The inclined land 73 is arcuate in transverse section, its centers of curvature lying on the axis of the rotor. The radius forming the inclined land 73 is shortest at the extreme end of the rotor and reaches its maximum length when the land 73 intersects the land 72 at the tip of the thread. The angle of inclination of the land 73 is complementary to the angle of the inclined wall 75 (FIGS. 1 and 2) which forms a part of the rotor housing 10. In this embodiment, each generating arc 76 is tangent to the land 73 at one end and tangent to the generated surface 78 of the thread at the other end, and at the extreme end of the rotor its center of curvature is substantially on the pitch circle 86, as shown, the length of the radius in this instance being substantially one-half the full height of the thread.

While the drawings show the threads at the extreme discharge end of the rotor as being substantially one-half as high as in the uniform section, it should be obvious that this invention need not have such a limitation. For example, the threads could be either greater or less than half their normal height at the discharge end. Further, the centers of the arcs forming the generating arcs 76 need not be exactly on the pitch circle and these arcs 76 need not be exactly true arcs. Should they not be true arcs they will generate a complementary portion 83 in the gate rotor trough and provide proper sealing.

In FIG. 31 the angle of inclination of the land 73 is shown as being about 45 degrees, and in FIG. 33 it is shown as being about 30 degrees, relative to the axis of the rotor. Although an angle of about 45 degrees is preferred, other angles would operate successfully. The gate rotors shown in FIGS. 30, 32 and 34 are complementary to the main rotor threads shown in FIGS. 29, 31 and 33, respectively.

Since liquid cooling of rotors of this type is old in the blower art, cooling passages are not shown in this disclosure. However, it is apparent that the non-uniform portion of the gate rotor can be enlarged to provide for cooling in the high temperature end where extra cooling is necessary, and that there is ample area in the main rotor for the circulation of cooling fluid.

Viewing the end of the gate rotor as shown in FIG. 30, a small convex surface 81 will be seen in the bottom of the trough 68. However, due to the steep helix angle of the rotor threads, this convex surface does not exist when the rotor is cut at a right angle to the rotor trough, and there is no conical surface in this rotor trough as

there is in the rotors of Whitfield Patent No. 2,922,377. This difference in the bottom of the gate rotor trough is important because the absence of the conical surface provides a concave shape that can be fully generated with a rotary type generator to extreme accuracy which is an important feature of this invention. If these rotors were not relical there would be a very small convex surface in the bottom of the gate rotor trough at the extreme discharge end as shown in FIG. 30. However, with the steep helix angle, which is necessary to produce high internal compression, the convex surface completely disappears.

FIG. 39 is a diagrammatic transverse section of the main rotor taken on line A—A of FIG. 33, about midway of the length of the inclined land 73. Each generating arc 76 is here smaller than that shown in FIG. 29 because the arc gradually decreases in size from the extreme discharge end of the rotor to the point of intersection of the inclined nonuniform section 55 with the generated uniform section 54 (FIG. 2). In this instance, the generating arcs 76 may become congruent with the gate rotor troughs only at the extreme discharge end of the rotors. However, each generating arc 76 generates a certain portion 83 of the gate rotor trough (FIG. 40), and it is not necessary that they become congruent to maintain a proper seal, even at the extreme end. If not congruent at the extreme discharge end, the only disadvantage is that small pockets will be developed and all the fluid will not be discharged.

Since the shape and size of the suction port 60 and discharge port 58 do not form a part of this invention, the ports will be described only in a general way.

As shown in FIG. 2, the suction port 60 is partially in the end wall and partially in the cylindrical chamber walls of the housing 10. The boundary of the port is located by the threads of the rotors when the threads are so positioned that a pocket has developed to substantially its maximum size, it being understood that the speed of operation may slightly affect the size of this port. Should the port close too early the pockets would not be completely filled, and should the port close too late some of the fluid would be discharged through the suction port.

The boundary of the discharge port is located by the threads of the rotors when the threads are so positioned that a given pocket has decreased in size by the amount required to compress the fluid to a predetermined pressure inside the unit, i.e., by internal compression. When the required pressure is produced, the threads register with the edge of the discharge port and further rotation of the rotors causes the fluid to be discharged.

For extremely high speed operation the suction port may be located entirely in the end wall to eliminate the action of centrifugal force on the fluid. In such a design the outline of the port in the end wall would still be determined by the location of the ends of the threads when they have formed a pocket of maximum size.

A brief description of a method of producing the rotors of the present invention in their simplest form may be as follows:

The main rotor 34 is generated and finished complete, with the exception of the inclinded lands, and would appear similar to the main rotor in the Whitfield Patent No. 2,486,770, FIG. 2. It could be generated on a machine as shown in the Whitfield Patent No. 2,792,763. The non-uniform sections of both rotors would also be generated on a machine of this general type. The cutters for cutting the non-uniform sections would be unlike those shown in the above patent but the generating principle would be exactly the same. Alternatively, the inclined lands 73 could be formed as by turning a taper in a lathe. The sharp corners 100 (FIG. 42) formed at the intersections of the inclined land surfaces 73 and the generated sides 78 of the threads are removed by forming the generating arcs 76. The troughs of the gate rotor are complementary to, and completely described or generated by, the main rotor threads. The form of the gate rotor is definitely fixed after the form of the main rotor is established. There is no rolling motion between the rotors except the rolling of the gate rotor lands 70 on the lands 74 at the root of the main rotor threads; and since all of these lands 70 and 74 are cylindrical, they are easy to produce. The entire thread surface of the main rotor, including the generating arcs 76, may be generated, and the entire trough surface of the gate rotor may be generated in a complementary manner.

In FIG. 42 is shown the small amount of metal which must be removed after the inclined land 73 is finished to provide each generating arc 76. This metal, between the sharp edge 100 and the rounded arc 76, may be removed by a generating process to provide perfect tangency of the arc 76 with the inclinded land 73 and the generated side 78 of the thread. Generation of arc 76 would provide extreme accuracy and ease of duplication.

FIGS. 35 and 36 represent a pair of rotors having an abrupt change in shape of the main rotor teeth and the gate rotor troughs instead of the gradual change shown in the preferred forms of FIGS. 31–34. The abrupt change in form may be desirable for certain methods of manufacture, but small sealed pockets would be formed with such a design.

While the device of the present invention has been described for use generally as a pump, blower, compressor or supercharger for reasons of simplicity, the same features that make it desirable for such uses also make it highly adaptable for use as a meter, an air motor, an hydraulic motor, a steam motor, an explosion motor, a measuring device, and numerous other uses in a wide variety of fields. It is especially suitable as a meter, when used without internal compression, since the elimination of sealed pockets also eliminates all internal work done between the rotors, whereby the device operates with almost no pressure drop across it.

While the invention has been described and illustrated in several preferred embodiments, including certain important details, it should be understood that the inventive concept is not limited to the precise structures and details herein illustrated and described, but may be carried out in various other ways falling within the scope of the appended claims.

What is claimed is:

1. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports arranged diagonally opposite each other adjacent to the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section throughout their length consisting of a main rotor and a gate rotor each having a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperating with each other and said housing to form pockets at the suction port, to advance said pockets and the fluid therein axially along the rotors and to exhaust the fluid at the discharge end of the rotors through the discharge ports as the rotors revolve in opposite directions about the axes thereof, the rotors being held in timed relation by timing gears and the threads of each rotor cooperating with the troughs of the mating rotor and with said housing chamber walls to provide fixed close running clearances which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

each of said rotors having a uniform section and a non-uniform section, the uniform sections extending from the suction end of the rotors to a point intermediate the ends of said rotors and the non-uniform sections extending from the discharge end of the rotors to the uniform section;

the main rotor characterized by having uniform cylindrical lands throughout its length at the root of the

threads and uniform cylindrical lands throughout the uniform section at the tips of the threads, the sides of the threads throughout their length being generated by the crest edges of the gate rotor, the tips of the threads in the non-uniform section being cut away in a generally tapered manner to form inclined lands, said inclined lands beginning at the tips of the threads at the junction between said uniform and non-uniform sections and terminating at the discharge end of the rotor, the length of the inclined lands being less than the normal axial dimension of the discharge port and the height of the threads being reduced by substantially one-half at the discharge end of the rotor, the sharp edges formed by the intersections between the inclined lands and the sides of the threads being rounded to form generating arcs, said arcs being substantially tangential to the inclined lands and the sides of the threads, said inclined lands being widest at the discharge end of the rotor to form unbroken seal lines with the gate rotor as the rotors revolve in timed relation; and

the gate rotor being characterized by having inclined lands at the root of the troughs in the non-uniform section of said rotor complementary to the inclined lands of said main rotor and generating surfaces in said troughs.

2. A fluid displacement device as set forth in claim 1 wherein the main rotor is further characterized by the inclined lands in the non-uniform section thereof being generated by the complementary inclined lands at the root of the troughs in the non-uniform section of the gate rotor, and the rounded edges of said inclined lands being generated by the complementary generating surfaces in the gate rotor troughs.

3. A fluid displacement device as set forth in claim 1 wherein the gate rotor is further characterized by the inclined trough portions in the non-uniform section thereof being generated by the complementary inclined lands on the main rotor threads.

4. A fluid displacement device as set forth in claim 1 wherein the gate rotor is further characterized by having each of the cylindrical lands cut away in a manner to form a shallow groove, there being a relatively narrow wear strip adjacent each generating edge of the gate rotor, and wherein the main rotor is further characterized by having each of the cylindrical and inclined lands cut away to form a shallow groove, there also being a narrow wear strip on each side of each of said shallow grooves in said main rotor, said grooves in the main and gate rotors being filled with a material different from the rotor material adapted to wear away readily upon contact with the housing while the rotors are in operation.

5. A fluid displacement device as set forth in claim 1 wherein the gate rotor is further characterized by having each of the cylindrical lands cut away in a manner to form a shallow groove, there being a relatively narrow wear strip adjacent each generating edge of the gate rotor, and wherein the main rotor is further characterized by having each of the cylindrical lands at the tip of the threads cut away to form a shallow groove, there also being a narrow wear strip adjacent each crest edge of the main rotor, said shallow grooves in the main and gate rotors being filled with a material different from the rotor material adapted to wear away readily upon contact with the housing while the rotors are in operation, the said wear strips being located slightly away from the extreme edges of the rotors to allow heat generated by friction during operation to dissipate readily into the body of the threads.

6. A fluid displacement device as set forth in claim 1 wherein the sharp edges formed by the intersection between the inclined lines and the sides of the threads are broken.

7. A fluid displacement device as set forth in claim 1 wherein the gate rotor is characterized by the crest edge of the rotor thread being cut away perpendicular to the lands to form a well-defined outer edge and the generating edge being formed by an arc of small radius, one end of which is tangent with the generated side of the trough, the other end terminating at the root of a wear strip adjacent the crest edge.

8. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports arranged diagonally opposite each other adjacent to the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section throughout their length and consisting of a main rotor and a gate rotor each having a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperating with each other and said housing to form pockets at the suction port, to advance said pockets and the fluid therein axially along the rotors and to exhaust the fluid at the discharge end of the rotors through the discharge port as the rotors revolve in opposite directions about the axes thereof, the rotors being held in timed relation by timing gears and the threads of each rotor cooperating with the troughs of the mating rotor and with said housing chamber walls to provide fixed close running clearances which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

each of said rotors having a uniform section and a non-uniform section, the uniform section extending from the suction end of the rotors to a point intermediate the ends of said rotors and the non-uniform section extending from the discharge end of the rotors to the uniform section the length of the non-uniform section being substantially less than the length of the uniform section;

the main rotor characterized by having cylindrical lands at the root of the threads which are substantially uniform throughout the length of the rotor, cylindrical lands at the tips of the threads which are uniform throughout the length of the uniform section, and inclined lands at the tips of the threads extending throughout the length of the non-uniform section, said inclined lands tapering lengthwise from the cylindrical lands at the tip of the threads of the uniform section toward the roots of said threads and increasing in peripheral extent, being widest at the discharge end of the rotor, the height of said inclined lands at the discharge end of the rotor being substantially greater than the height of the cylindrical lands at the roots of the threads, the sharp edges formed by the intersections between the lands and the sides of the threads being rounded; and

the gate rotor characterized by the sides of its threads in the uniform section being generated by the crest edges of the main rotor threads, and the threads in the non-uniform section being arc generated by the rounded edges of the inclined lands of the main rotor, there also being relatively narrow inclined trough portions at the root of said gate rotor threads in the non-uniform section which blend into the arc generated sides of said threads, the length of the non-uniform section being less than the normal axial dimension of the discharge portion, the troughs being substantially one-half as deep at the extreme discharge end of the gate rotor as in the uniform section thereof, and the lands at the tips of the gate rotor threads being cylindrical and substantially uniform throughout their length.

9. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports arranged diagonally opposite each other adjacent to the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section

throughout their length and consisting of a main rotor and a gate rotor each having a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperating with each other and said housing to form pockets at the suction port, to advance said pockets and the fluid therein axially along the rotors and to exhaust the fluid at the discharge end of the rotors through the discharge port as the rotors revolve in opposite directions about the axes thereof, the rotors being held in timed relation by timing gears and the threads of each rotor cooperating with the troughs of the mating rotor and with said housing chamber walls to provide fixed close running clearances which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

each of said rotors having an axially extending uniform section and an axially extending non-uniform section, the uniform section extending from the suction end of the rotors and terminating intermediate the ends of the rotors and the non-uniform section extending from the discharge end of the rotors and terminating at the uniform section, the length of the non-uniform section being substantially less than the length of the uniform section;

the main rotor characterized by having cylindrical lands at the root of the threads which are substantially uniform throughout the length of the rotor, cylindrical lands at the tip of the threads which are uniform throughout the length of the uniform section, and inclined lands extending throughout the length of the non-uniform section, said inclined lands being arcuate with the centers of curvature lying on the axis of said rotor and the inclined lands being widest at the discharge end of the rotor, the sides of the main rotor threads being generated throughout their length by the crest edges of the gate rotor and the edges formed at the intersections between the inclined lands and generated sides of the main rotor threads being rounded and complementarily generated by complementary generated portions of the gate rotor trough in the non-uniform section of the gate rotor; and

the gate rotor characterized by having cylindrical lands at the tips of the threads, said lands having crest edges and being substantially uniform throughout their length, the sides of the gate rotor threads in the uniform section of said rotor being generated by the crest edges of the main rotor, and having inclined lands in the troughs of the non-uniform section complementarily generated by the complementary inclined lands on the main rotor, the sides of the threads in the non-uniform section of said gate rotor being complementarily generated by the complementarily generated by the complementary rounded edges of the inclined lands on the main rotor such that while the unit is in operation, the entire inclined surface of the main rotor has a greater peripheral speed than the peripheral speed of the inclined surface of the gate rotor and providing a relative sliding motion between the inclined land surfaces of the said rotors and also providing a trough in the non-uniform section of the gate rotor that is wider than the thickness of the complementary main rotor thread, which provides the extra space necessary for the said sliding relative motion between the two inclined land surfaces.

10. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports arranged diagonally opposite each other adjacent to the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section throughout their length and consisting of a main rotor and a gate rotor each having a a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperating with each other and said housing to form pockets at the suction port, to advance said pockets and the fluid therein axially along the rotors and to exhaust the fluid at the discharge end of the rotors through the discharge ports as the rotors revolve in opposite directions about the axes thereof, the rotors being held in timed relation by timing gears and the threads of each rotor cooperating with the troughs of the mating rotor and with said housing chamber walls to provide fixed close running clearances which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

the gate rotor characterized by having cylindrical lands and concave troughs, said lands and troughs being uniform throughout the length of the rotor, the lands and troughs forming crest edges at their intersections, each of said crest edges being cut away by a relatively large arc which is tangential with the cylindrical land and non-tangential with the side of the trough and a second smaller arc which is tangential with both said first arc and the side of the trough to produce a rounded generating edge, and the sides of the gate rotor threads being generated by the crest edges of the main rotor;

the main rotor characterized by having a substantial portion of the sides of the threads of the main rotor at the tip being generated by a constantly changing point on the said smaller arc and the remainder of the thread to the root being generated by a constantly changing point on the said relatively large arc, there being no congruency of surfaces between either of said arcs and the main rotor thread, except at the root, the said large and small arcs arranged to reduce the width of the gate rotor land by the maximum amount while providing the minimum size of leakage opening created by breaking the crest edge of said rotor.

11. A fluid displacement device as set forth in claim 10 wherein the gate rotor is further characterized by having each of its crest edges cut away by a relatively large arc which is tangential with the cylindrical land and non-tangential with the side of the trough and a second smaller arc which is tangential with both said first arc and the side of the thread to produce a rounded generating edge, and wherein the main rotor is complementary.

12. In a fluid displacement device having a housing provided with diagonally opposite suction and discharge ports arranged therein respectively adjacent opposite ends of said housing and said housing also having intersecting cylindrical bores, a pair of mating threaded helical rotors symmetrical in cross section throughout their length and consisting of a main rotor and a gate rotor each having threads and troughs and rotatably supported within said cylindrical bores of said housing and cooperating with each other in said housing to form pockets at the suction end and advance the same axially along the rotors and exhaust at the discharge end of the housing through the discharge port as the rotors revolve in opposite directions about the axes thereof, the threads of each rotor having a close running fit with the troughs of the mating rotor within which troughs said threads are received as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

each of said rotors having a uniform section and non-uniform section, the uniform section extending from the suction end of the rotors to a point intermediate of the ends of said rotors and the non-uniform section extending from the discharge end of the rotors to the uniform section, the length of the non-uniform section being substantially less than the uniform section, each of said rotors having inclined lands in the non-uniform section, the inclined lands on the main rotor threads being cut away in a gen-

erally tapered manner toward the discharge end of the rotor, the sharp edges of the intersection formed between the inclined land and the sides of the threads being rounded and the non-uniform section of the gate rotor being complementarily generated by the inclined land and rounded edges of the main rotor, wherein, while the unit is in operation, the entire inclined surface of the main rotor has a greater peripheral speed than the peripheral speed of the inclined surface of the gate rotor and providing a relatively sliding motion between the inclined land surfaces of the said rotors and also providing a trough in the non-uniform section of the gate rotor that is wider than the thickness of the complementary main rotor thread, which provides the extra space necessary for the said sliding relative motion between the two inclined land surfaces.

13. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports at the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section throughout their length and comprising a main rotor and a gate rotor each having a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperating with each other and said housing to form pockets at the suction end of the housing and to advance said pockets to the discharge end as the rotors revolve in opposite directions about the axes thereof, the threads of each rotor cooperating with the troughs of the mating rotor and with said housing to provide close running clearances which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

each of said rotors having a uniform section extending axially from the suction end of the rotors to a point short of the discharge end of the rotors wherein the threads and troughs of said rotor are of uniform shape and size, and a non-uniform section extending axially from said uniform section to the discharge end of said rotor wherein the threads and troughs are of non-uniform shape and size;

the main rotor being characterized by having cylindrical lands at the roots of the threads which are substantially uniform throughout the length of the rotor, cylindrical lands at the tips of the threads which are uniform throughout the length of the uniform section, the tips of the threads in the non-uniform section being tapered to form inclined lands extending throughout the length of the non-uniform section, said inclined lands tapering lengthwise from the cylindrical lands of the threads of the uniform section toward the roots of said threads and increasing in peripheral extent, being widest at the discharge end of the rotor, the length of the inclined lands being less than the normal axial dimension of the discharge port, the height of said inclined lands at the discharge end of the rotor being greater than the height of the cylindrical lands at the roots of the threads, the sharp edges formed by the intersections between the inclined lands and the sides of the threads being rounded to form generating arcs substantially tangential to the inclined lands and the sides of the threads, said inclined lands being widest at the discharge end of the rotor to form unbroken seal lines with the gate rotor as the rotors revolve in timed relation; and

the gate rotor being characterized by having cylindrical lands at the tips of the threads which are substantially uniform throughout the length of the rotor, concave troughs which are uniform throughout the length of the uniform section, and concave troughs having concave inclined lands at the bottoms thereof throughout the length of the non-uniform section, the troughs of said non-uniform section of the gate rotor being complementary to and generated by the threads of the non-uniform section of the main rotor.

14. A fluid displacement device as set forth in claim 13 wherein the flanks of the threads of said non-uniform main rotor section have portions extending outwardly from the roots thereof generated by the crests of the gate rotor threads and arcuate portions merging tangentially into said crests and said generated portions.

15. A fluid displacement device as set forth in claim 13 wherein the lands of the threads of the non-uniform section of the main rotor taper in height from the height of the lands in the uniform section of said main rotor to approximately one-half said height at the discharge end of said rotor.

16. A fluid displacement device as set forth in claim 13 wherein the non-uniform sections of said rotors are disposed wholly within the axial dimension of said discharge port.

17. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports arranged diagonally opposite each other adjacent to the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section throughout their length and consisting of a main rotor and a gate rotor each having a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperatng with each other and said housing to form pockets at the suction port, to advance said pockets and the fluid therein axially along the rotors and to exhaust the fluid at the discharge end of the rotors through the discharge port as the rotors revolve in opposite directions about the axes thereof, the rotors being held in timed relation by timing gears and the threads of each rotor cooperating with the troughs of the mating rotor and with said housing chamber walls to provide fixed close running clearance which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

each of said rotors having an axially extending uniform section and an axially extending non-uniform section, the uniform section extending from the suction end of the rotors and terminating intermediate the ends of the rotors and the non-uniform section extending from the discharge end of the rotors and terminating at the uniform section, the length of the non-uniform section being substantially less than the normal axial dimension of the discharge port;

the main rotor characterized by having cylindrical lands at the roots of the threads which are substantially uniform throughout the length of the rotor, cylindrical lands at the tip of the threads which are uniform throughout the length of the uniform section, and inclined lands extending throughout the length of the non-uniform section, said inclined lands being arcuate with the centers of curvature lying on the axis of said rotor and the inclined lands being widest at the discharge ends of the rotor, the sides of the main rotor threads being generated throughout their length by the crest edges of the gate rotor and the edges formed at the intersections between the inclined lands and generated sides of the main rotor threads being rounded and generated by complementary generated portions of the gate rotor trough in the non-uniform section of the gate rotor;

the main rotor being complementary and further characterized by having each of the cylindrical and inclined lands cut away to form a shallow groove, there also being a narrow wear strip on each side of said shallow grooves in said main rotor, said grooves in the main and gate rotors being filled with a material different from the rotor material adapted to

wear readily upon contact with the housing while the rotors are in operation; and

the gate rotor characterized by having cylindrical lands at the tips of the threads, said lands having crest edges and being substantially uniform throughout their length, each of the lands being cut away in a manner to form a shallow groove, there being a relatively narrow wear strip adjacent each generating edge of the gate rotor, each of said crest edges being cut away by a relatively large arc which is tangential with the cylindrical land and non-tangential with the side of the trough and a smaller arc which is tangential with both said relatively small arc and the side of the thread to produce a rounded generating edge, the sides of the gate rotor threads in the uniform section of said rotor being generated by the crest edges of the main rotor, and having inclined lands in the troughs of the non-uniform section generated by the complementary inclined lands on the main rotor, the sides of the threads in the non-uniform section of said gate rotor being generated by the complementary rounded edges of the inclined lands on the main rotor.

18. In a fluid displacement device of the type having a housing provided with intersecting cylindrical rotor chambers and suction and discharge ports arranged diagonally opposite each other adjacent to the opposite ends of the housing, and a pair of complementary mating helically threaded rotors symmetrical in cross section throughout their length and consisting of a main rotor and a gate rotor each having a plurality of threads and troughs, said rotors being rotatably supported within the chambers of said housing and cooperating with each other and said housing to form pockets at the suction port, to advance said pockets and the fluid therein axially along the rotors and to exhaust the fluid at the discharge end of the rotors through the discharge port as the rotors revolve in opposite directions about the axes thereof, the rotors being held in timed relation by timing gears and the threads of each rotor cooperating with the troughs of the mating rotor and with said housing chamber walls to provide fixed close running clearances which effectively seal said pockets against leakage as the rotors are rotated to advance the pockets therealong, the improvement which comprises:

the gate rotor characterized by having cylindrical lands and concave troughs, said lands and troughs being uniform throughout the length of the rotor, the lands and troughs forming crest edges at their intersections, each of said crest edges being cut away by a relatively large arc which is tangential with the cylindrical land and non-tangential with the side of the trough and a second smaller arc which is tangential with both said first arc and the side of the trough to produce a rounded generating edge, and the sides of the gate rotor threads being generated by the crest edges of the main rotor,

the gate rotor being further characterized by having each of the cylindrical lands cut away in a manner to form a shallow groove, there being a relatively narrow wear strip adjacent each generating edge of the gate rotor,

the main rotor being complementary and characterized by having uniform cylindrical lands at the tips and roots of the threads, the sides of the main rotor threads being generated by constantly changing points on the arcs of the rounded generating edges of the gate rotor and there being a fillet at the root of each thread, said fillets being complementary to the rounded edges of the gate rotor threads, said fillets and rounded edges of the gate rotor becoming congruent as the rotors revolve to form an unbroken seal line the full length of the rotors,

the main rotor being further characterized by having each of the cylindrical lands at the tip of the threads cut away to form a shallow groove, there also being a narrow wear strip adjacent each crest edge of the main rotor, said shallow grooves in the main and gate rotors being filled with a material different from the rotor material adapted to wear away readily upon contact with the housing while the rotors are in operation, the said wear strips being located slightly away from the extreme edges of the rotors to allow heat generated by friction during operation to dissipate readily into the body of the threads.

References Cited by the Examiner

UNITED STATES PATENTS

2,174,522	10/1939	Lysholm	230—143
2,504,230	4/1950	Smith	230—143
2,622,787	12/1952	Nilsson	103—125
2,922,377	1/1960	Whitfield	103—125

FOREIGN PATENTS

908,116	2/1959	Great Britain.

MARK NEWMAN, *Primary Examiner.*

SAMUEL LEVINE, *Examiner.*

W. L. FREEH, *Assistant Examiner.*