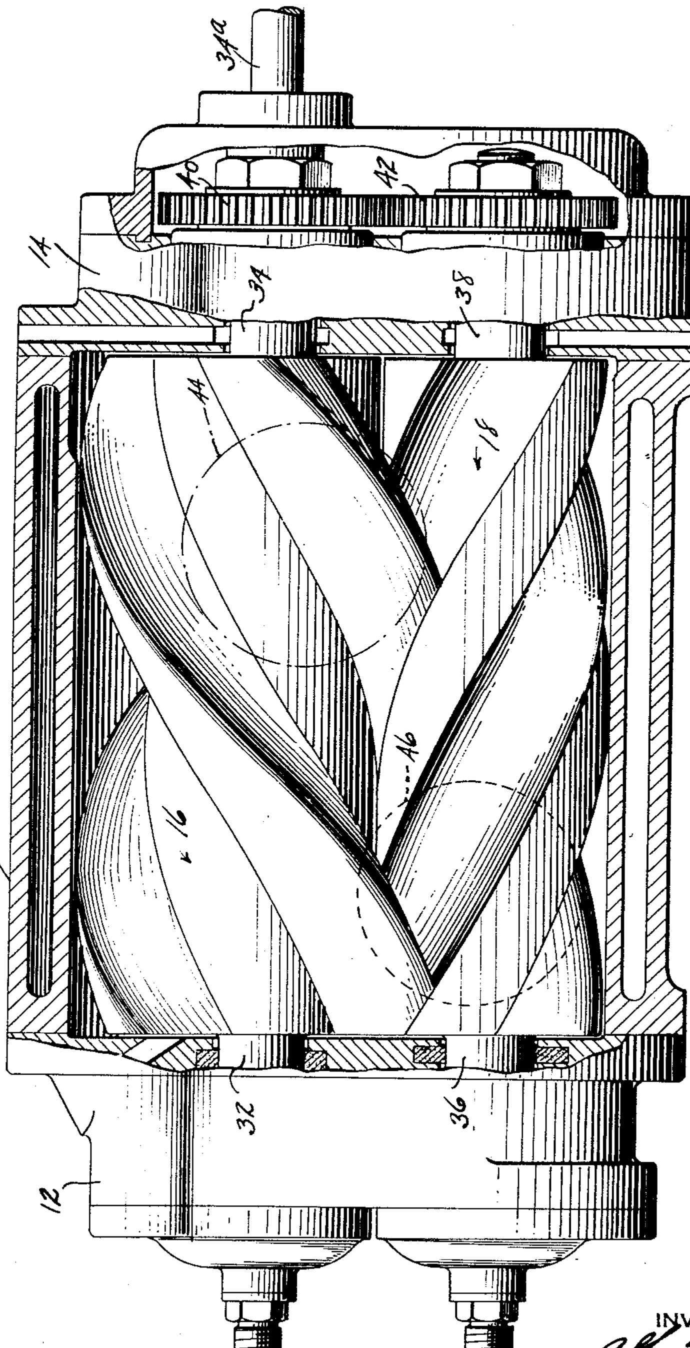
Oct. 3, 1939. A. LYSHOLM 2,174,522

ROTARY SCREW APPARATUS

Filed Jan. 6, 1938 3 Sheets-Sheet 1

Fig. 1.



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INVENTOR
Alf Lysholm
Daniel L. Marble
His ATTORNEY

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ROTARY SCREW APPARATUS

Filed Jan. 6, 1938 3 Sheets-Sheet 2

Fig. 3.

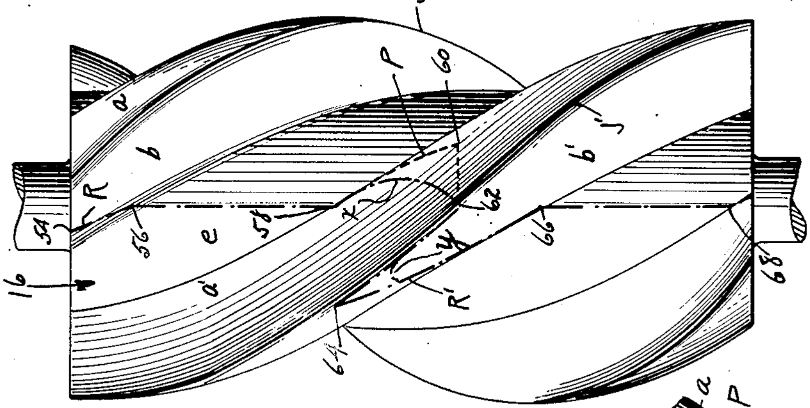


Fig. 2a.

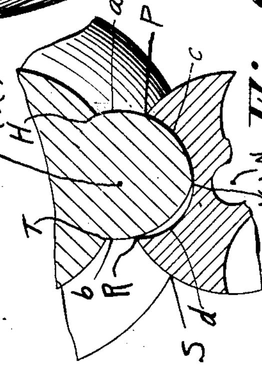
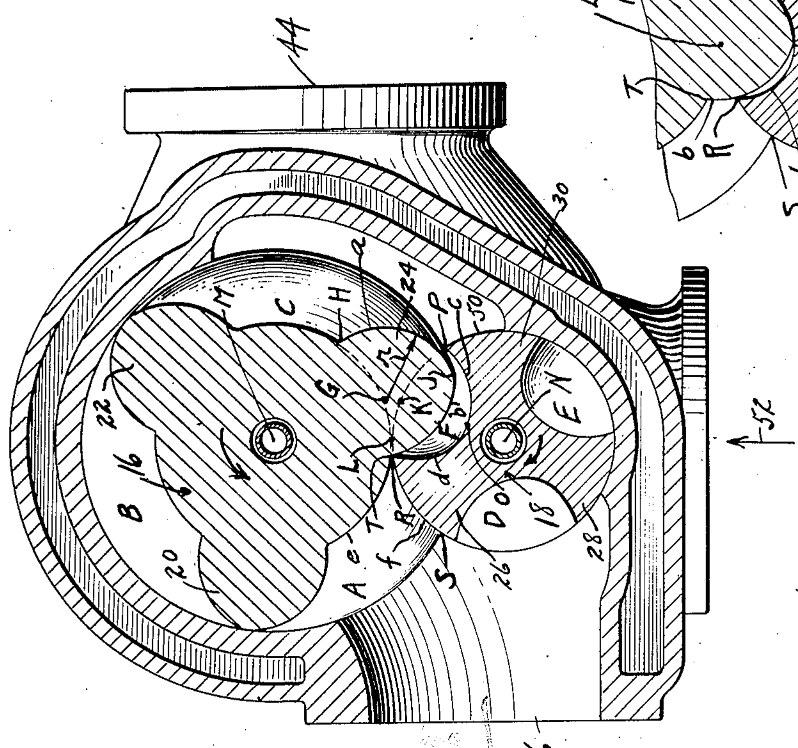


Fig. 2.



INVENTOR
Alf Lysholm
BY
Jarvis C. Marble
his ATTORNEY

Oct. 3, 1939. A. LYSHOLM 2,174,522

ROTARY SCREW APPARATUS

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Fig. 5.

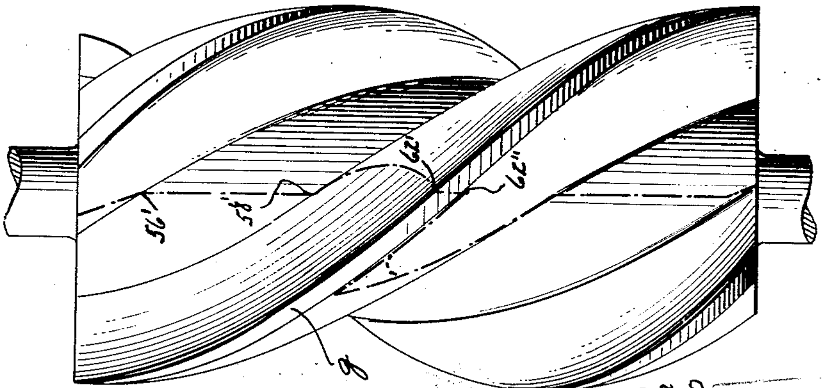


Fig. 6.

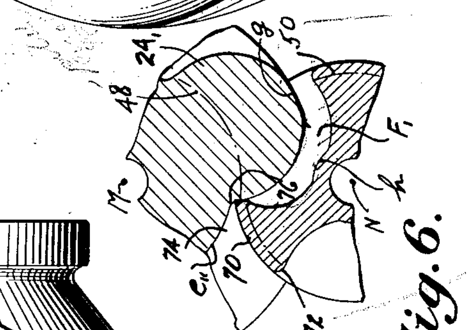
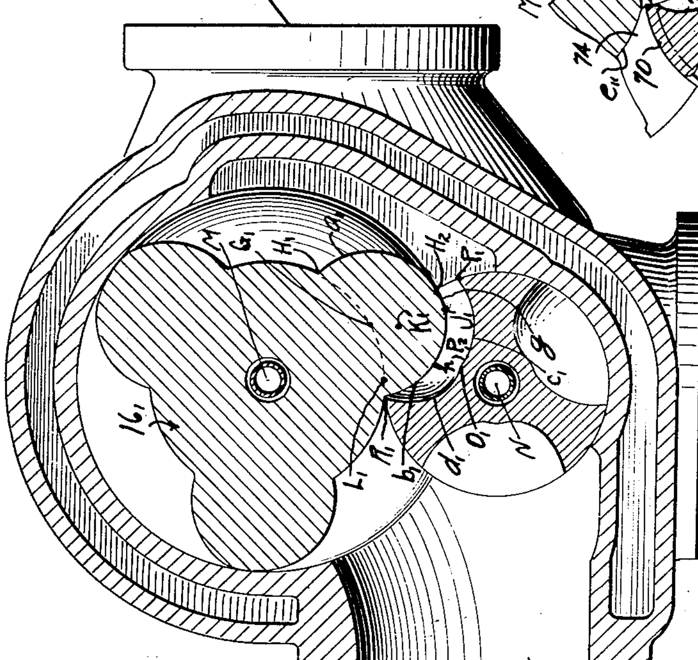


Fig. 4.



INVENTOR
Alf Lysholm
BY
Daniel C. Maible
his ATTORNEY

UNITED STATES PATENT OFFICE

2,174,522

ROTARY SCREW APPARATUS

Alf Lysholm, Stockholm, Sweden

Application January 6, 1938, Serial No. 183,664
In Sweden February 12, 1935

21 Claims. (Cl. 230—143)

This application is a continuation-in-part with respect to my copending application Serial No. 44,935, filed October 14, 1935, and as to common subject matter contains matter divided out from said application Serial No. 44,935.

The present invention relates to apparatus of the rotary screw type, that is, apparatus of the kind comprising two or more rotors having intermeshing spiral lobes and grooves cooperating with each other and a suitable casing to form working spaces for the transport of fluid. While the invention is considered to be of primary utility in apparatus of this kind having working spaces of variable volume utilized to compress gaseous media, it may also be applied to rotary screw devices adapted merely for displacement pumping and to rotary screw type engines. Because of its importance in connection with compressor apparatus, the invention is hereinafter described in its application to such apparatus, but it is to be understood that other apparatus is included within the scope of the invention.

In apparatus of the character under consideration, the working spaces are determined in part by the lines where the rotor lobes most closely approach the inner wall of the casing, and in part by the line where the rotors most closely approach each other. These lines are between relatively moving bodies and it will be evident that the efficiency of the apparatus will to a very material extent depend upon the amount of fluid leaking from the working chambers past such lines. From this it follows that in so far as the factor of leakage is concerned, it is desirable to make the lines of closest approach which in part define the extent of the working chambers, as short as possible, and a primary object of the present invention is to provide rotors having intermeshing lobes and grooves of novel form which will provide working chambers limited by such lines having substantially less length than has heretofore been obtainable with previous forms of construction.

The manner in which the invention is carried into effect and its more detailed nature and advantages may best be understood from a consideration of the ensuing portion of this specification, taken in conjunction with the accompanying drawings, in which suitable forms of apparatus are described by way of example.

In the drawings:

Fig. 1 is a broken side view of a compressor embodying the invention;

Fig. 2 is a section taken on the line **2—2** of Fig. 1;

Fig. 2*a* is a fragmentary section showing part of the rotors shown in Fig. 2 in a different position;

Fig. 3 is an elevation of one of the rotors of the device shown in Fig. 1;

Fig. 4 is a section similar to Fig. 2, showing another embodiment of the invention;

Fig. 5 is a view similar to Fig. 3, but of the rotor form shown in Fig. 4; and

Fig. 6 is a fragmentary section showing still another form.

Referring now to the drawings, the compressor illustrated comprises a casing **10** having end structures **12** and **14**.

In the embodiment shown, two rotors are employed, consisting of a male rotor indicated generally at **16** and a female rotor indicated generally at **18**, the rotor **16** being provided with three spiral lobes **20**, **22**, and **24**, and the rotor **18** being provided with three spiral grooves D, E, and F, with which the respective lobes of rotor **16** are adapted to intermesh.

It will be understood that the present invention is not limited to the number of intermeshing rotors that may be employed, nor to the number of lobes and grooves, all of which factors may be varied in apparatus of this character without departing from the general principle of the invention. The size of the rotors is chosen so that the theoretical top circle of the female rotor and the theoretical root circle of the male rotor coincide with the pitch circles and for purposes of describing the invention, the rotors have been illustrated and will be described with no clearance between each other or between themselves and the surrounding casing.

With the above stated relationship of the theoretical top and root circles of the rotors to the pitch circles, it will be evident that any two intermeshing rotors must necessarily be very different in their cross-sectional characteristics, as distinguished from rotors of the "Roots" type or like types in which the intermeshing rotors have like cross-sectional characteristics. For convenience, the terms "male" and "female" are herein employed to designate rotors having the characteristic feature of being unlike in profile characteristics.

In this connection it is to be noted that for the purpose of securing high efficiency of operation, particularly for compressors, I prefer to provide and maintain clearance between the intermeshing portions of the rotors and between the rotors and the casing, and to operate the rotors at relatively very high surface speeds. The provision of such clearance, which should be the minimum that is practical and which is preferably of the order of 0.2 millimeter, provides what may be termed "space packing", which when employed in conjunction with high speeds of operation, forms a packing which is adequate to enable high efficiencies to be obtained and which possesses certain very definite advantages. The absence of contact permits speeds of operation, and consequently capacity for a given size of compressor, greater than is possible with relatively moving surfaces which are in frictional contact with each other, and the space packing further enables dry rotors to be used which is of material advantage in that it eliminates the difficulty of having the gaseous medium compressed in the compressor contaminated by lubricating oil or oil vapor. The features relating to the specific character of packing employed, speed of operation, etc., form per se no part of the invention herein claimed, and are included in the subject matter claimed in my copending application Serial No. 44,935.

As this description proceeds, it will become evident that in so far as the present invention is concerned, the specific means employed to prevent leakage of fluid from the working chambers may be varied and other packing means may be employed, as for example, a film of oil between the closely adjacent parts, or packing strips intended to make contact with cooperating surfaces. It will further be evident that regardless of the specific type or kind of packing relied upon, the portions of the parts which most closely approach each other provide lines which in part limit the extent of the working spaces. These lines may be said to constitute packing lines or lines of packing for the working chambers, and hereinafter such lines between the relatively moving parts, which constitute lines limiting the extent of the working chambers, will be referred to as packing lines or lines of packing, with the understanding that such terms are not limiting with respect to the type of packing employed, which may be the preferred space packing or other form.

Referring again to Fig. 1, the rotors **16** and **18** are provided with shaft parts at their ends, such parts on the rotor **16** being designated at **32** and **34** and the corresponding parts on rotor **18** being designated at **36** and **38**.

The shaft parts are carried in bearings of any suitable form (not shown) housed in the casing end structures **12** and **14**, and in the preferred form illustrated, the rotor **18** is driven by means of gears **40** and **42** mounted on the shaft parts **34** and **38** respectively, the compressor being driven through the power input extension **34a** on the shaft part **34**. The gears **40** and **42** maintain the rotors in peripherally spaced relation to maintain the preferred space packing provided by clearance between the intermeshing rotor parts and in this connection it is to be noted that in the event space packing is employed, the bearings carrying the rotors should be capable of absorbing axial thrust to prevent the rotors from making the actual contact with each other which would result from relative axial displacement thereof.

In the embodiment illustrated, the inlet for the medium to be compressed and the outlet for the compressed medium are at opposite sides of the casing **10**, the inlet being indicated at **44** and the outlet at **46**. As will be observed from Fig. 1, ports **44** and **46** are axially displaced with respect to each other in addition to being on opposite sides of the casing.

In so far as the present invention is concerned, the specific shape of the ports at the intersection of the port walls with the curved inner wall of the casing is not an essential feature of construction and the end walls of the casing adjacent to the ends of the rotors may be relieved over a certain portion of their areas so that either or both the inlet and the outlet ports may provide axial as well as radial admission and/or delivery of the working fluid. Detailed description and illustration of the specific forms of the port openings, preferred forms of which constitute a part of the subject matter of my copending application Serial No. 44,935, are consequently not described herein.

In the general operation of the apparatus, compression is effected by the formation of closed working spaces which are displaced axially with diminishing volume after the limiting edges of the spaces have passed the confines of the inlet port and before such limiting edges come into registry with the outlet port.

As will be appreciated from Figs. 1 and 2, assuming the rotors to be turning in the direction indicated by the arrows in Fig. 2, air or other gaseous medium to be compressed will be drawn into the spaces A, B, and C between the lobes of rotor **16** and into the grooves D, E, and F of the rotor **18** as these spaces and grooves pass the inlet port opening. The air confined in these spaces and grooves is carried therein without compression, after the spaces and grooves have passed out of registry with the inlet port, until the lobes **26**, **28**, and **30** on the female rotor successively enter the spaces A, B, and C and effect compression by progressively reducing the volume of these spaces as the rotors continue to revolve. At the time the lobes on the female rotor enter the spaces between the lobes on the male rotor, these spaces are out of communication with the outlet port. As the rotors continue to revolve, the groove immediately behind the lobe on the female rotor which is reducing the volume of a given space in the male rotor, is brought into direct communication with such space. Thereafter the working space in which compression takes place is formed by one of the spaces in the male rotor and a cooperating groove in the female rotor, the volume of the groove in the female rotor being progressively diminished by the entry into it of the cooperating lobe on the male rotor as the rotors further continue to revolve. The working space is continuously decreased in volume until the edges of the rotor lobes defining the space come into registry with the outlet port, at which time discharge of the compressed medium takes place.

In the position of the rotors shown in Fig. 2, the working space formed by space A and groove D is shown as discharging to the outlet port **46** and it will be evident from the figure how the volume of space A has been reduced by entry into it of the lobe **26** on the female rotor. Due to the spiral curvature of the lobes and grooves, the volume of the groove D, with the rotors in the position shown, has been substantially reduced before the rotors have reached the point shown, by entry of the lobe **20** into groove D, behind the plane of the section.

Space B and groove E are shown in compressing positions, the spiral lobe **28** entering the space B behind the plane of the paper and the spiral lobe **22** on the male rotor also being in position to enter the space E, it being appreciated that as viewed in Fig. 2, both space E and lobe **22** curve to meet each other at a place behind the plane of the drawings and on the side of the compressor opposite the inlet port. Space C and groove F are in communication with the inlet port in the position of the rotors shown in the figure.

As the spiral lobes roll into their respectively cooperating grooves or spaces, the working spaces will in part be defined by the lines of packing between the edges of the lobes and the casing and in part by the lines of packing between the lobes and the cooperating grooves or spaces.

If the profiles of the lobes and grooves are generated curves so that such profiles are symmetrical, the packing line between any given lobe and its cooperating groove will be in the form of a long loop extending axially of the lobe for a very considerable distance, the cross-section in the plane normal to the axes of the rotors showing a crescent shaped space between the flanks of the lobe and the sides of the groove in the plane of the section.

In accordance with the present invention, the long loop of the packing line between lobe and groove is very substantially shortened and brought as nearly as possible to the ideal condition of having such line follow the perimeter of the lobe in the plane of a transverse section.

I have found that the desired ideal condition is most nearly obtained by employing an asymmetric lobe profile and an asymmetric groove profile, the most important distinguishing characteristic of which is the shaping of the profiles on the pressure side of the lobe and groove so that the curves of these sides coincide with each other in the plane of rotation of the rotors, leaving no substantial clearance, when the summit of the profile is directly in the line joining the axes of the two cooperating rotors.

The ideal condition desired may be very closely approached by making the profile of the pressure flank of the lobe in the form of a circular arc. When this is done, and the corresponding side of the cooperating groove is likewise made in the form of a circular arc of the same radius, the desired conditions are substantially met. The conditions obtained by exact circular arcs may be somewhat improved upon by slight deviations therefrom, as will hereinafter be more fully explained, but for practical purposes the nature of the desired profile may best be explained in connection with an embodiment in which an exact circular arc is employed and such an embodiment will now be described with particular reference to Figs. 2 and 2*a*.

lobe flank circular arc

In this embodiment, the form of the profile for the lobes and grooves is obtained in the following manner: From a point G located on the root circle **48** of the male rotor as a center, a circular arc HJ is drawn, the radius *r* of which is equal to the height GJ of the lobe. This arc provides one side or flank *a* of the profile of the lobe, this flank being on the pressure side and referred to as the pressure flank. A point K is determined on the top circle **50** of the female rotor so that it will meet the point G at point L lying on a line connecting the axes M and N of the rotors. Since points G and K always move at the same velocity due to the fact that they lie on the pitch circles, their distances from the point L are always the same. With K as a center, a circular arc OP is drawn which has the same radius *r* as the arc HJ and which extends from the point of intersection O with the line KN to the point of intersection P with the top circle **50**.

The arc OP forms one side *c* of the groove, hereinafter referred to as the pressure side of the groove.

As will be observed from Fig. 2*a*, when the profile lines *a* and *c* are obtained in the manner indicated, these lines coincide when points G and K meet at point L, and it will further be evident from this figure that with the rotors in this position, the pressure side of the lobe entirely fills the pressure side of the groove.

The point R limiting the opposite or suction side of the groove is determined by the condition that points R and J must meet at the point of intersection S of the two top circles of the rotors, and the suction side or flank *b* of the lobe extending from the point J to the point T is generated by the point R, that is, point R touches the flank *b* over its entire length from J to T.

generated

The suction side *d* of the groove from O to R is in turn generated by the point J at the summit of the lobe profile.

It will, of course, be evident that the points and lines shown in Fig. 2 are such only with respect to the cross-sectional or profile view. When considering the rotors as a whole, the point J, for example, is a line at the summit of the lobe profile while the lines such as *a* and *b* represent the side surfaces or flanks of the lobe.

As will be evident from Figs. 2 and 2*a*, the profiles of the lobes and grooves are asymmetrical, one side thereof in each case being a circular arc and the other side being a generated curve the nature of which is such that the profile of the lobe is asymmetrical with respect to a radius passing through its summit, and the profile of the groove is asymmetrical with respect to a radius passing through the bottom of the groove. Also, it will be noted that the radii of curvature of the generated sides of the profiles are larger than the radius of the curvature *r* of the sides of the profiles determined by this latter radius.

lobe profile generated curve

In order to illustrate the character of the packing line obtained with profiles of the above described character, Fig. 3 shows the rotor **16** viewed in the direction of the arrow **52** in Fig. 2, the packing line, that is, the line of closest approach of the two rotors to each other, being shown by a dot and dash line. The portion of the packing line **54—56** on the surface *b* is determined by the position of the line R. This portion is followed by a portion **56—58** parallel to the axis of the rotor and formed by the approach along this axis of the cylindrical surface *e* formed at the root circle of the male rotor and the cylindrical surface *f* formed at the top circle of the female rotor. The theoretical packing line, that is, the line obtained with no clearance between the rotors, then extends along the line P to point **60** and then on the line of intersection of surface of flank *a'* and a plane normal to the axis of the rotor, to the intersection with the line J', at **62**. The theoretical packing line then follows the line J' to the intersection with the line R' at point **64**. It then follows line R' to point **66**. From this point the patch of the packing line is again parallel to the axis to the point **68**, the path from point **66** on, if extended, being a repetition of the path from point **56** to point **66**.

If there is clearance between the rotors, the packing line, that is, the line of closest approach between the rotors, is slightly different from the theoretical line just described. With clearance, the portion of the theoretical line **58**, **60**, **62**, which has been shown in dotted lines, is altered to the curved line x directly connecting points **58** and **62**. Likewise, with clearance, the packing line does not follow lines J' and R' to their intersection at point **64** but follows the curved line y which joins lines J' and R' short of their point of intersection.

Were it not for the special form of the lobe and groove profiles, the packing line between the points **58** and **62** would extend axially of the flank a' of the lobe for a very much greater distance, in the form of a long loop, than is the case with the construction shown, and consequently the chance for loss of fluid from the working spaces is very greatly diminished by the present construction and the efficiency of the apparatus correspondingly increased.

When the point P is at the root of the lobe profile, approximately at the point H (which occurs before the rotors reach the position shown in Fig. 2a) and from that point until the point P reaches the position shown in Fig. 2a, this point should travel substantially in contact with curve a if the most highly efficient packing is to be obtained. Point P substantially does this with the exact circular curves indicated in the drawings but for the most nearly perfect construction the portion of curve a between the points P and H in Fig. 2a may have very slightly increasing radius of curvature toward the root of the profile. In practical forms of construction, when this increasing radius of curvature is employed, the deviation from a true circular arc is usually only a fraction of a millimeter in the case of a rotor of the order of 150 millimeters diameter. Accordingly, it is to be understood that for the purposes of this specification and the appended claims, the term "substantially circular" or equivalent terms are intended to include such deviation as that just described.

In the apparatus hereinbefore described it will be noted that the pressure and suction sides or flanks of the profiles meet in a point giving a summit to the lobe which is in the form of an apex line.

In so far as the present invention is concerned, the advantages are not confined to this specific lobe profile, but may be equally advantageously employed with lobe profiles having flattened summits and this latter type is shown in Figs. 4 and 5.

In the embodiment shown in these figures, the general construction of the casing and the rotors is the same as shown in Figs. 2 and 3 and need not again be described in detail.

Considering first the profile of the lobes on the male rotor **16**$_1$, the curve b_1 of the suction flank is the same as in the previously described embodiment, being generated by the point R_1 on the female rotor. Likewise, the curve d_1 of the suction side of the groove in the female rotor is generated from point R_1 to O_1 by the point J_1 at the summit of the suction flank b_1.

On the pressure side of the male lobe, curve a_1 is arcuate as in the previous embodiment with a radius r struck from a point on the pitch circle of the male rotor. In this instance, however, the point G_1 from which this radius is struck is not located on the radius extending from the axis of rotation of the rotor to the point J_1, but is offset therefrom as shown in Fig. 4. As a result the extent of the curve a_1 providing the pressure flank of the lobe is from point H_1 to point H_2 and the summit of the profile is formed by a cylindrical surface g. In effect, the present form of the lobe profile is formed by moving the curve a of Fig. 2 peripherally and parallel to itself to the position of the curve a_1 in Fig. 4.

The pressure side of the curve in the present modification, formed by the curve c_1, is as in the previously described form an arc having the radius r struck from a point K_1 on the pitch circle of the female rotor, so placed that it will meet point G_1 at point L_1. Curve c_1 extends from P_1 to point P_2 and between this point and point O_1, the bottom of the groove is formed by the convex cylindrical surface h which is in rolling contact with the surface g on the male rotor as the rotors pass a position corresponding to the position of the rotors shown in Fig. 2a.

By comparing Fig. 5 with Fig. 3 it will be observed that the character of the packing line between the lobe and the groove is, with respect to the flanks of the lobe and sides of the groove, the same in this embodiment as in the embodiment shown in Fig. 2. The only difference in the character of the packing line in the present embodiment is that in the present case the line **56'**—**58'** is shorter than in the previous embodiment and that between point **62'** and point **62''** an additional packing line parallel to the axis of the rotor is introduced. The length of this additional line **62'**—**62''** just equals the reduction in the length of the line **56'**—**58'** as compared with line **56**—**58** (Fig. 3), so that the total length of the packing line remains unchanged.

From a purely theoretical standpoint, the form of profile having a sharp apex line J shown in Figs. 2 and 3 is preferable since with the sharp apex line, the spaces between the lobes, and consequently the working chambers of the apparatus, can be made of maximum capacity for a given diameter of rotor. Also, as will be observed by comparison of Figs. 2 and 4, the form of profile shown in Fig. 2 permits a heavier lobe section to be employed for a female rotor of given pitch diameter.

On the other hand, practical considerations make sharp edges undesirable, particularly where the dimensions of the rotors are held to very close limits, as in cases where it is desired to use high speeds of rotation and space packing. In such cases ground cylindrical surfaces at the summits of the lobe profiles are desirable, for purposes of accurate measurement and other reasons, even if such surfaces have but very slight width in peripheral direction.

It will be understood, of course, that to obtain flat summits, if they are comparatively very narrow, the general form of profile shown in Fig. 2 may be used and a small portion of the summit ground off and the bottom of the groove correspondingly altered, to get substantially the same effect as is shown in somewhat exaggerted form in Fig. 4.

For practical reasons it is also desirable to avoid the sharp edges limiting the grooves in the female rotor and in order to avoid this, the female rotor may be extended to provide a small addendum extending beyond the pitch circle of the rotor, the male rotor being correspondingly reduced in diameter between the lobes.

The form of lobe and groove profile shown in Fig. 4 is illustrated in Fig. 6 with this modification included. Referring now to this figure the pitch circles of the rotors are indicated at **48** and **50** respectively and the lobes of the female rotor are extended beyond the pitch circle to provide an addendum portion **70**, which in the figure is, for the sake of clearness, shown very much larger in proportion to the radius of the rotor than would be desirable in practice.

Within the pitch circle **50** the form of the groove F_1 is the same as shown in Fig. 4 and outside the pitch circle **48** the lobe **24_1** on the male rotor is the same as shown in Fig. 4. At its edges each of the addendum portions **70** is rounded off as at **72** to eliminate the undesirable sharp edges and where the cylindrical portion e_{11} of the male rotor is cut away below the pitch circle **48** to provide the dedenum portion **74**, the root portion of the profile is filleted as at **76** to correspond with the rounded corners **72** on the female rotor.

From the foregoing it will be apparent that the exact form of profile may be varied within the scope of the invention but certain characteristics are common to all forms giving the advantages desired. Among such characteristics are the following: The lobes on the male rotor lie entirely or substantially entirely outside the pitch circle of the rotor; the profiles of the male lobes are of generally convex form while the profiles of the female grooves are of generally concave form; both male lobes and female grooves are asymmetric in profile; and the pressure flanks of the male lobes comprise surfaces lying peripherally outside the positions of surfaces which would symmetrically correspond to the surfaces forming the suction flanks of the lobes.

It is to be understood that the scope of the invention is not to be limited to the specific apparatus shown herein by way of illustration but is to be considered as embracing all apparatus falling within the scope of the appended claims when they are construed as broadly as is consistent with the state of the prior art.

What I claim is:

1. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a packing line between the male rotor and the female rotor, said lobes and said grooves having asymmetrically shaped profiles to provide a packing line therebetween shorter than that obtainable with symmetrically shaped profiles.

2. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a packing line between the male rotor and the female rotor, the flanks of the profiles of the lobes of the male rotor being asymmetrically convex and the sides of the profiles of the cooperating grooves in the female rotor being asymmetrically concave to provide a shorter packing line than that obtainable with symmetrically shaped profiles.

3. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the flanks of the lobes on the male rotor being convex and asymmetrical with respect to any radius from the axis of the male rotor passing through a lobe profile and the profile of each of the sides of the grooves in the female rotor being concave and asymmetrical with respect to any radius from the axis of the female rotor passing through a groove.

4. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the flanks of the lobes on the male rotor being convex and asymmetrical with respect to any radius from the axis of the male rotor passing through the lobe profile and the pressure flank of the lobe being substantially a circular arc the center of which is located approximately on the pitch circle of the rotor, the profile of each of the sides of the grooves in the female rotor being concave and asymmetrical with respect to any radius from the axis of the female rotor passing through a groove, and the pressure side of the groove profile being approximately a circular arc of substantially the same radius as that of the arc forming the pressure flank of the lobe profile on the male rotor.

5. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor being convex and the pressure flank of the lobe having a larger radius of curvature than the minimum radius of curvature of the portion of the cooperating groove in the female rotor forming the suction side of the groove, and the profile of the sides of each of the grooves in the female rotor being concave and shaped so that in at least one position of rotation of the rotors the pressure flank of the lobe profile substantially coincides with the pressure side of the cooperating groove profile.

6. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor being convex and the pressure flank of the lobe having a larger radius of curvature than the minimum radius of curvature of the portion of the cooperating groove in the female rotor forming the suction side of the groove, and the profile of the sides of each of the grooves in the female rotor being concave and shaped so that in the position of the rotors in which the summit of a lobe on the male rotor intersects the plane extending through the axes of rotation of the rotors, the pressure flank of the lobe profile on the male rotor substantially coincides with the pressure side of the cooperating groove profile.

7. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the flanks of the profile of each of the lobes on the male rotor being convex and asymmetrical with respect to any radius from the axis of the male rotor passing through a lobe

profile, the pressure flank of the lobe profile being in the form of substantially a circular arc the center of which is located approximately on the pitch circle of the rotor and the suction flank of the lobe profile being generated by a point on the surface of said female rotor at the edge of a groove therein and the sides of the profile of each of the grooves in the female rotor being concave and asymmetrical with respect to any radius from the axis of the female rotor passing through a groove.

8. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor and the profile of each of the grooves in the female rotor including on one side a curve in the form of substantially a circular arc and on the other side a curve generated by a point located on the surface of the other rotor.

9. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, each of the lobes on the male rotor having convexly curved side flanks meeting to form a lobe summit substantially in the form of a line, the pressure flank of the lobe being substantially circularly curved in profile and the suction flank of the lobe profile being a surface generated by the pitch line edge of the corresponding side of the cooperating groove, and each of the grooves in the female rotor having concavely curved sides merging at the bottom of the groove, the pressure side of the groove being in the form of a substantially circularly curved surface having approximately the same radius of curvature as that of the pressure flank of the cooperating lobe and which on the suction side of the groove is in the form of a curve generated by the summit edge of the suction flank of the cooperating lobe.

10. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, each of said rotors having cylindrical surfaces substantially at the pitch circles of the rotors, the lobes of the male rotor lying entirely outside the cylindrical surfaces of the male rotor and the grooves in the female rotor lying entirely within the cylindrical surfaces of the female rotor, the profile of each of the flanks of the lobes on the male rotor being convexly curved and the curvature being different on different sides of the summit of the lobe, and the profile of each of the sides of the grooves being concavely curved and the curvature being different on different sides of the bottom of the groove.

11. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a packing line between the male rotor and the female rotor, each of the lobes on the male rotor having a suction flank comprising a surface generated by a line approximately at the pitch circle of the female rotor and a pressure flank comprising a surface lying peripherally outside the position of a surface symmetrically corresponding to the surface of the suction flank, and each of the grooves of the female rotor having concave sides appropriately formed to cooperate with the lobes on the male rotor.

12. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a packing line between the male rotor and the female rotor, each of the lobes of the male rotor having a suction flank comprising a surface generated by a line approximately at the pitch circle of the female rotor and a pressure flank comprising a convexly curved surface lying peripherally outside the portion of a surface symmetrically corresponding to the surface of the suction flank and each of the grooves of the female rotor having sides concavely curved to cooperate with the lobes on the male rotor.

13. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a packing line between the male rotor and the female rotor, each of the lobes of the male rotor having a suction flank comprising a surface generated by a line approximately at the pitch circle of the female rotor and a pressure flank comprising approximately a circular arc lying peripherally outside the portion of a surface symmetrically corresponding to the surface of the suction flank and each of the grooves of the female rotor having sides concavely curved to cooperate with the lobes on the male rotor.

14. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a packing line between the male rotor and the female rotor, each of the lobes on the male rotor having a suction flank portion lying outside the pitch circle of the rotor which is generated by a line approximately at the pitch circle of the female rotor and a pressure flank comprising a surface lying peripherally outside the position of a surface symmetrically corresponding to the generated surface of the suction flank, each of the grooves of the female rotor having sides appropriately concavely formed inside the pitch circle of the female rotor to cooperate with the lobes on the male rotor and having addendum portions with rounded edges extending slightly beyond the pitch circle of the female rotor, the portions of the male rotor between the lobes thereof lying slightly inside the pitch circle of the rotor to accommodate said addendum portions.

15. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor

and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, each of the lobes on the male rotor having a pressure flank in the form of substantially a circular arc the center of which is located approximately at the pitch circle of the rotor and a suction flank generated by a line approximately at the pitch circle of the female rotor, and each of the grooves of the female rotor having a pressure side curved on approximately the same radius of curvature as the pressure side of the cooperating lobe on the male rotor and a suction side generated by a line approximately at the pitch circle of the male rotor.

16. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a line of approximate contact between the male rotor and the cooperating surface of the female rotor, said lobes and said grooves having asymmetrically shaped profiles to provide a line of approximate contact therebetween shorter than that obtainable with symmetrically shaped profiles.

17. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces each defined in part by a line of approximate contact between the male rotor and the cooperating surface of the female rotor, the profiles of the lobes of the male rotor being asymmetrically convex and the profiles of the grooves in the female rotor being asymmetrically concave to provide a shorter line of approximate contact therebetween than is obtainable with profiles of symmetrical shape.

18. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor being convex and asymmetrical with respect to a radius of the male rotor intersecting the apex of the lobe profile, and the portion of the profile on the pressure side of the lobe being a circular arc the center of which is located approximately on the pitch circle of the rotors, and the profile of each of the grooves in the female rotor being concave and asymmetrical with respect to the projection of the radius of minimum length from the axis of the female rotor to the surface of the groove.

19. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor being convex and the portion of the profile on the pressure side of the lobe having a smaller radius of curvature than the portion on the remainder of the lobe profile, and the profile of each of the grooves in the female rotor being concave and shaped so that in at least one position of rotation of the rotors the profile of the lobe substantially coincides with the corresponding profile of the groove.

20. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor being convex and the portion on the pressure side of the lobe having a smaller radius of curvature than the remaining portion, the profile of the cooperating groove in the female rotor being concave and shaped so that in the position of the rotors in which the apex of a lobe on the male rotor intersects the plane extending through the axes of rotation of the rotors, the profile of the lobe on the male rotor substantially coincides with the profile of the cooperating groove in the female rotor.

21. In apparatus of the rotary screw type, a casing having an inlet and an outlet, a male rotor and a female rotor mounted for rotation in said casing and having intermeshing spiral lobes and grooves, respectively cooperating with each other and with the interior surface of the casing to form working spaces, the profile of each of the lobes on the male rotor being convex and asymmetrical with respect to a radius of the male rotor intersecting the apex of the lobe profile, the portion of said profile on the pressure side of the lobe being in the form of an arc the center of which is located approximately on the pitch circle of the rotors and the remainder of said profile being generated by a point on the surface of said female rotor at the edge of a groove thereof, and the profile of each of the grooves in the female rotor being concave and asymmetrical with respect to the projection of the radius of minimum length from the axis of the female rotor to the surface of the groove.

ALF LYSHOLM.