Jan. 19, 1965 R. E. WHITE ETAL 3,166,238

AXIAL COMPRESSOR

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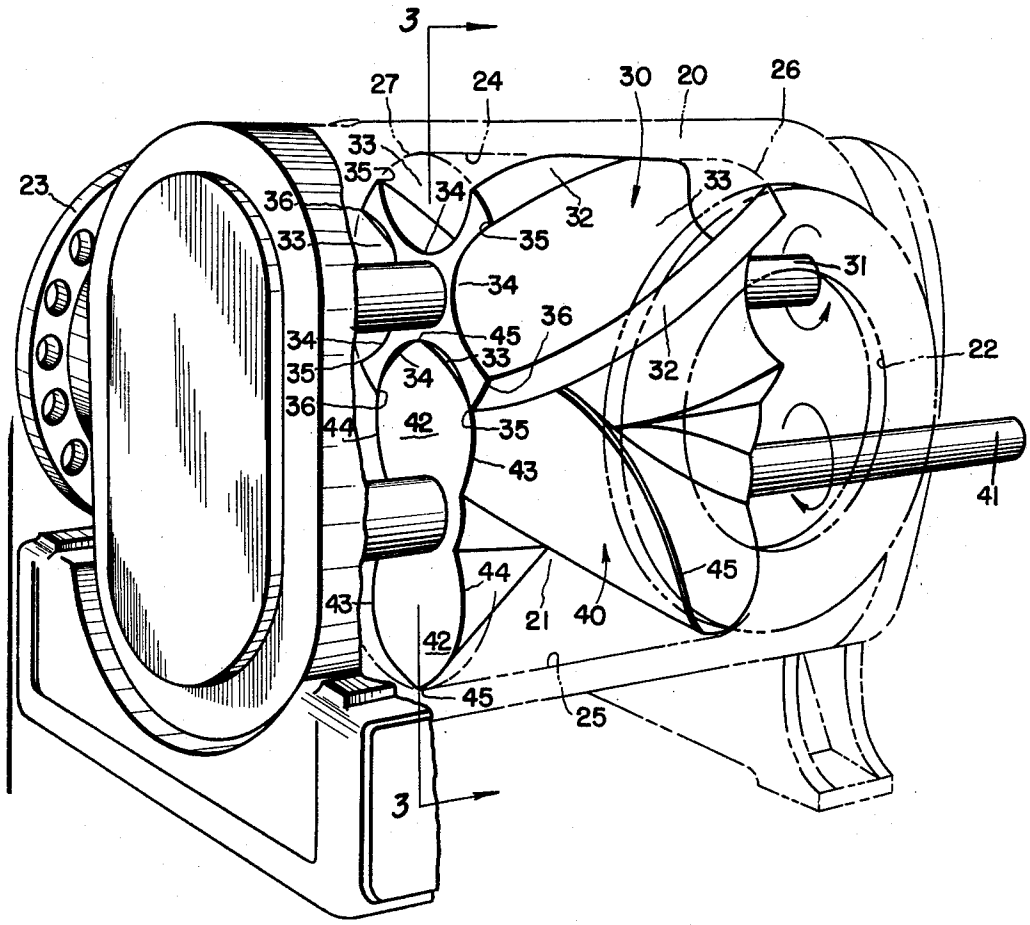


FIG. 1

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AXIAL COMPRESSOR

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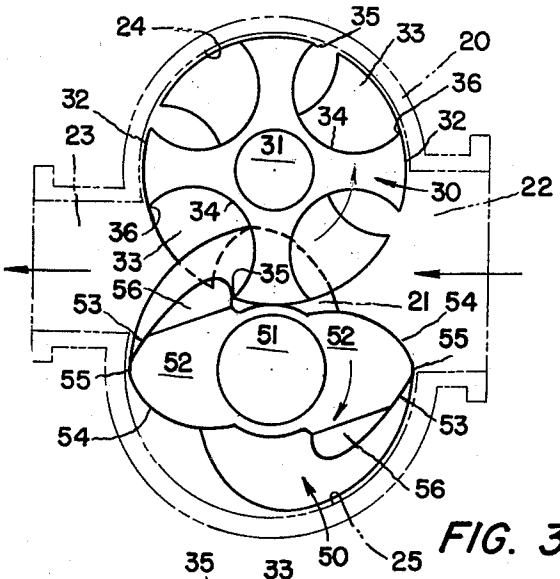


FIG. 3

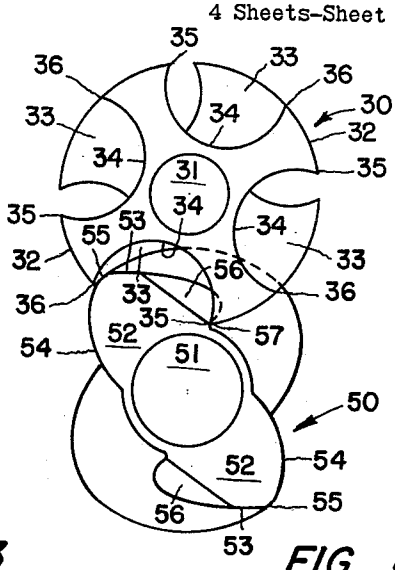


FIG. 4

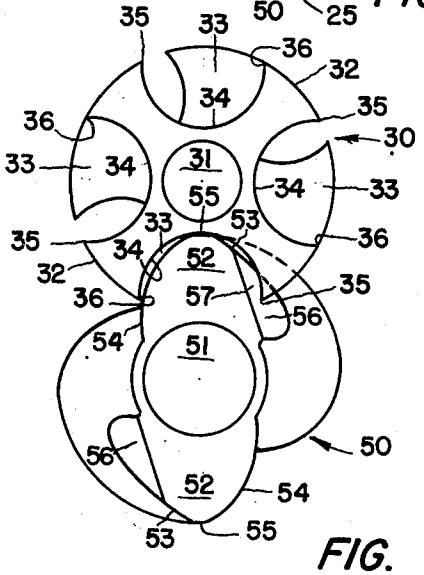


FIG. 5

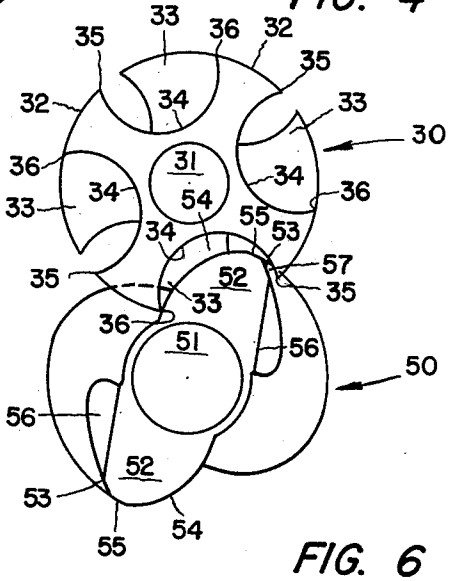


FIG. 6

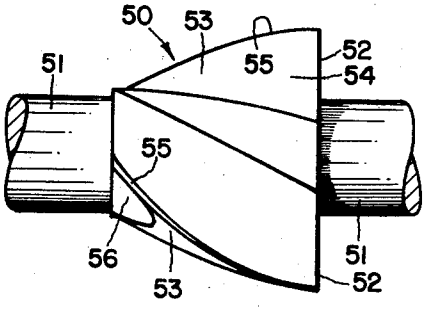


FIG. 2

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AXIAL COMPRESSOR

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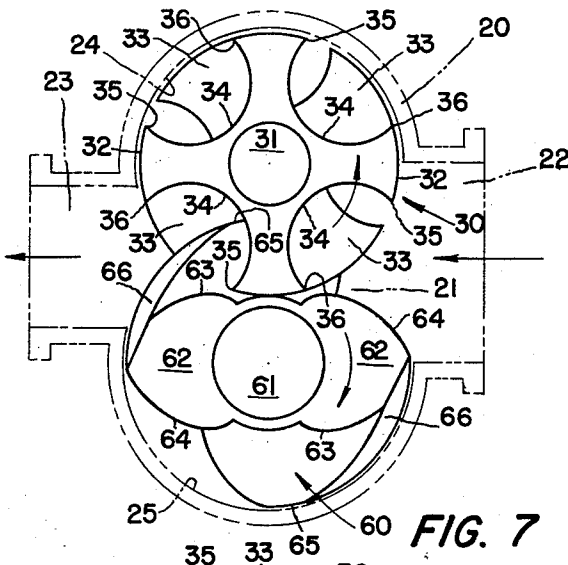


FIG. 7

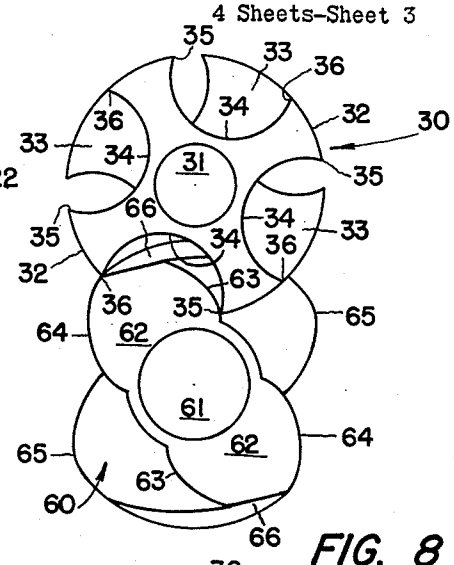


FIG. 8

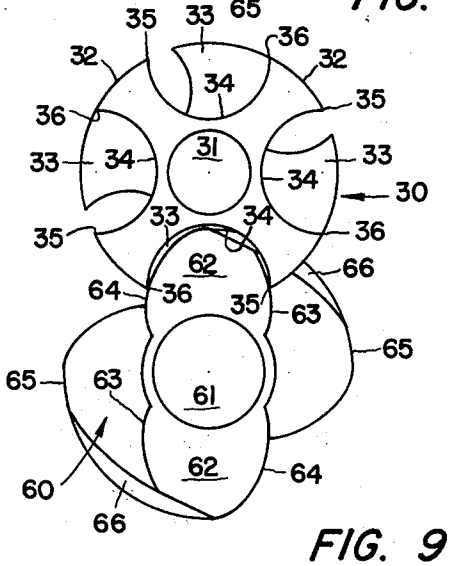


FIG. 9

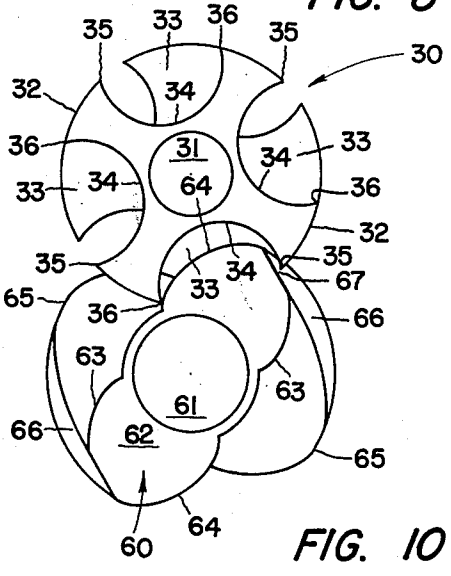


FIG. 10

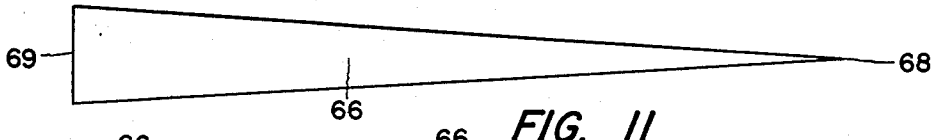


FIG. 11

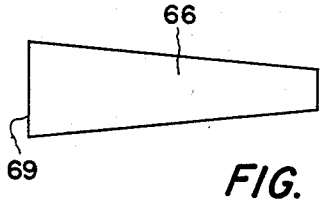


FIG. 12

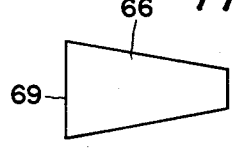


FIG. 13

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AXIAL COMPRESSOR

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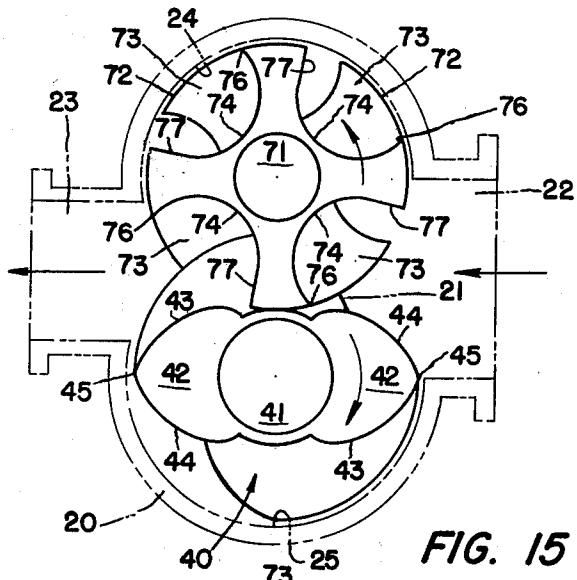


FIG. 15

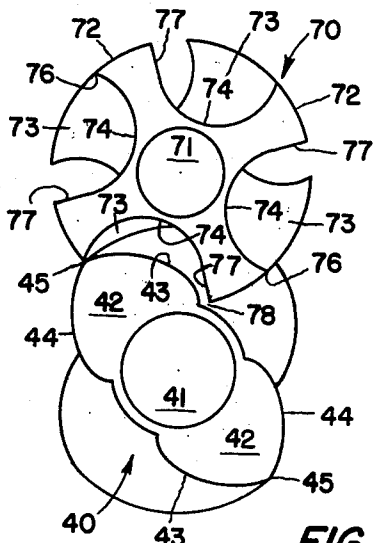


FIG. 16

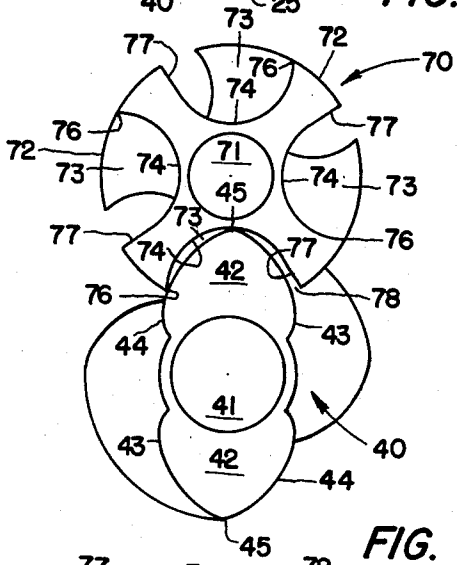


FIG. 17

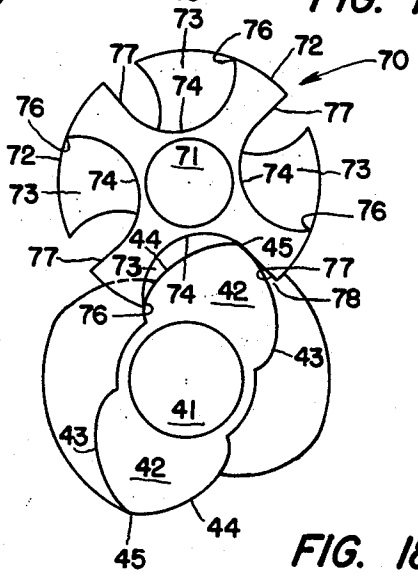


FIG. 18

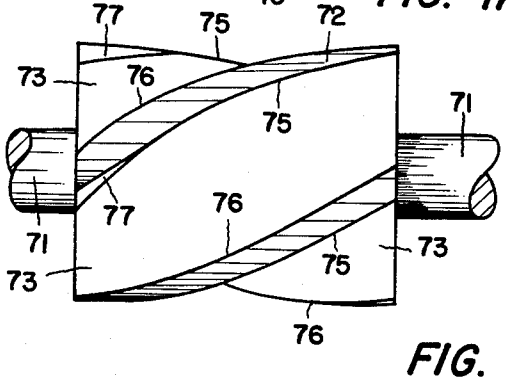


FIG. 14

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United States Patent Office 3,166,238 Patented Jan. 19, 1965

3,166,238

AXIAL COMPRESSOR

Richard E. White and John B. Marsden, Corning, N.Y., assignors to Ingersoll-Rand Company, New York, N.Y., a corporation of New Jersey

Filed Aug. 1, 1962, Ser. No. 214,085
4 Claims. (Cl. 230—143)

This invention generally relates to axial compressors, pumps, blowers and the like having a pair of rotary members with meshing helical threads, and relates more particularly to providing such rotary members with means for preventing fluid traps therebetween at the discharge or outlet end. The term compressor hereinafter will be used in a generic sense to also designate pumps, blowers and the like.

An axial compressor of the type considered is generally not new and comprises a pair of meshing helically threaded rotors disposed within a housing having an inlet and outlet at opposite ends thereof and on opposite sides of a plane generally extending through the centers of the rotation of both rotors. The threads of the rotors are complementary, commencing to mesh at the inlet end, and progressively mesh toward the discharge end of the compressor. This successive and progressive intermeshing forms carrier pockets receiving fluid at the inlet at one end of the compressor which is transported to the outlet at the other end of the compressor and forced out of such outlet by progressive reduction of the pocket volume. The threaded portions of the rotors are formed to provide seal lines between the rotors and the casing walls to prevent slippage of the fluid being compressed. At the terminal portion of the mesh, at the outlet end of the compressor, the seal lines together with the end wall of the casing define a pocket closed to both the compressor inlet and outlet thus forming a fluid trap with no escape path other than normal running clearances. When leakage between the discharge ends of the rotors and the end wall of the casing and between the rotors themselves are held to relatively precise limits, the pressure build-up in such fluid traps, due to progressive reduction of the trap volume, becomes so elevated that excessive power is required. Where a portion of the trapped fluid is incompressible, the resulting forces become much more severe and sometimes destructive, usually to the weaker gate rotor.

Many and various constructions to alleviate such trap conditons have been tried with relative success, however, they normally are attended by undesirable features such as weakened structure, abrupt changes of the flow path of the compressed fluid causing power losses, excessive leakage, etc. Probably the most common of such arrangements for alleviating traps are end grooves in the rotors and recesses in the end walls of compressors. Examples of such arrangements may be found in Patent 2,531,603 granted to W. F. Berck on November 28, 1950, Patent 1,991,541 granted to J. Cannizzaro on February 19, 1935, and Patent 2,620,968 granted to H. R. Nilsson on December 9, 1952. Other arrangements of a more complicated nature may be found in Patent 2,111,568 granted to a A. Lysholm et al. on March 22, 1938, Patent 2,578,196 granted to C. O. J. Montelius on December 11, 1951, and Patent 2,705,922 granted to G. Rathman on April 12, 1955. In addition, attempts have been made to increase running clearances thus reducing the effective seal between the rotor ends and the outlet end wall of the casing. Although such attempts were successful in obviating formation of fluid traps, the leakage afforded thereby reduced the efficiency of the compressor below desirable limits.

Fluid flow in an axial type compressor is along substantially a helical path wherein flow forces are primarily comprised of two force components; one axial relative

to the compressor, and the other circular conforming substantially to the compressor walls. When end wall recesses are provided to vent formed traps, fluid passing through such pockets requires reversal of the axial flow force component causing power waste. Where the ends of the rotors are slotted or grooved the terminal thread portions are weakened, expensive machining of the rotors is encountered, the size of the escape path is restrictive, and here again the problem of flow path directional change must be considered inasmuch as the flow path is now formed between the base of such slots or grooves and the end wall.

In view of the foregoing, an object of this invention is to prevent the pressure build-up due to entrapped fluid in an axial type compressor.

Another object of this invention is to provide means for reducing the required horsepower to operate an axial type compressor thereby increasing efficiency.

Another object of the invetion is to provide means for evacuating entrapped fluid between meshing rotors of an axial type compressor.

Another object of the invention is to permit an axial type compressor to pass a predetermined amount of non-compressible fluid therethrough without damage to the rotors.

Another object of this invention is to provide an axial type compressor having meshing rotors with relief paths to prevent formation of fluid traps between the rotor discharge ends, the rotors being machined with facility and with no loss of strength to provide such relief paths.

And, another object of this invention is to provide an axial type compressor having relief paths for formed fluid traps wherein flow therethrough is not attended by reversal of flow force components.

Still, another object of this invention is to provide an axial type compressor having intermeshing helically threaded rotors, the intermeshing threads there forming pockets defined by seal lines wherein a terminal portion of one of the seal lines of each pocket is removed to form an escape path and prevent formation of a fluid trap between meshing discharge ends of the rotors.

And, still another object of this invention is to provide an axial type compressor having intermeshing threaded rotors forming seal lines therebetween and between such threads and the compressor casing to provide pockets for receiving fluid at the inlet end of said compressor and discharging said fluid at the opposite end thereof wherein the terminal end of one of the seal lines of each pocket is removed to prevent formation of fluid traps at the discharge end of said compressor.

This invention contemplates an axial type compressor comprising a casing having a chamber with an inlet at one end, and an outlet at the other end, a pair of rotors disposed in the chamber, the inlet and outlet being disposed on opposite sides of the rotors relative to a plane through the axes of rotation of both rotors, the rotors having helically extending lobes and grooves meshing to form pockets at the inlet end of the compressor for receiving fluid and for compressing and discharging the compressed fluid through the outlet, the helical grooves being defined by arcuate wall surfaces generated by lobe crest edge surfaces and forming seal lines therewith, the arcuate wall surfaces having leading and trailing crest edge surfaces, the lobes having a leading flank surface generated by the leading crest edge surface and forming seal lines therewith, the lobes having trailing flank surfaces intersecting the leading flank surfaces to form lobe crest surfaces, the lobes and grooves tending to form fluid traps when in mesh between the seal lines at the outlet ends of the rotors, and all of one of the surfaces forming the seal lines being profiled to provide escape paths for

fluid from the outlet ends of the meshing lobes and grooves to prevent formation of fluid traps.

The foregoing and other objects and advantages of the invention will appear more fully hereinafter from a consideration of the detailed description which follows, taken together with the accompanying drawings wherein several embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for illustration purposes only and are not to be construed as defining the limits of the invention.

FIGURE 1 is a perspective view of a pair of intermeshing helically threaded axial compressor main and gate rotors with a casing enclosing the rotors,

FIGURE 2 is a plan view of the main rotor of FIGURE 1 modified or profiled in accordance with the invention,

FIGURES 3, 4, 5, and 6 are diagrammatic views taken generally on line 2—2 of FIGURE 1 illustrating progressive positions of the rotors with the main rotor modified as shown in FIGURE 2; the casing being indicated in FIGURE 3,

FIGURES 7, 8, 9, and 10 are diagrammatic views corresponding to FIGURES 3, 4, 5, and 6, respectively, with the main rotor having a modified profile; the casing being indicated in FIGURE 7,

FIGURES 11, 12, and 13 are developed diagrammatic views in flat pattern of the escape path provided in the arrangement of FIGURES 7 to 10, at various stages of the rotor rotation after the escape path is fully formed,

FIGURE 14 is a plan view of the gate rotor of FIGURE 1 modified or profiled in accordance with the invention, and

FIGURES 15, 16, 17, and 18 are diagrammatic views corresponding to FIGURES 3, 4, 5, and 6, respectively, with the gate rotor modified as shown in FIGURE 12; the casing being indicated in FIGURE 15.

Referring now to the drawings and particularly to FIGURE 1, an axial compressor being considered has a casing 20 to provide a chamber 21 therein with an inlet 22 at one end and an outlet 23 at the other end. Chamber 21 is formed by a pair of intersecting parallel bores defined by intersecting circular walls 24 and 25, and is closed at its ends by walls 26 and 27. A gate or female rotor 30 is disposed in the bore defined by wall 24 and meshes with a main or male rotor 40 in the bore defined by wall 25. The ends of rotors 30 and 40 form running seals with the end walls 26 and 27.

The gate or female rotor 30 is mounted on a shaft 31 for rotation in chamber 21 with its outer periphery 32 forming a running seal with circular wall 24. The gate rotor periphery 32 has four helically extending grooves 33 which are equally spaced from one another. Each of the grooves 33 are defined by an arcuate wall 34 generated by crest edge surfaces 45 of lobes 42 of the main or male rotor 40, and terminate in a leading crest edge surface 35 and a trailing crest edge surface 36.

The main or male rotor 40 is mounted on a shaft 41 for rotation in chamber 21 and has a pair of diametrically opposed, helically extending lobes 42. Each lobe 42 has leading flank surface 43 and a trailing flank surface 44 intersecting to form a crest edge surface 45 which forms a running seal with the chamber wall 25. The leading and trailing flank surfaces 43 and 44 are generated by the leading and trailing crest edge surfaces 35 and 36, respectively, of the grooves 33.

Accordingly, the grooves 33 of the gate rotor 30 and the lobes 42 of the main rotor 40 define helical threads which sequentially and progressively move into and out of mesh with one another, commencing at the inlet end of the compressor and terminating at the outlet end to sequentially form pockets that initially increase in volume to receive fluid from the inlet, then decrease in volume to compress fluid and force the compressed fluid through the outlet 23. It should be readily understood, that each of the crest edges or edge surfaces 35, 36, and 45 form seal lines with the respective surfaces 43, 44, and 34 which they generate. When there is terminal meshing of a groove 33 with a lobe 42, or the mesh extends to the outlet end of each rotor, a trap will be formed within the grooves 33 that is defined by the seal lines derived by the crest edge surfaces and the surfaces they generate.

The end of the formed trap is closed by the running seal between the rotors and the end wall 27, and the only escape path or exit for fluid trapped therein is the normal running clearance provided between the moving parts. It has been found that normal leakage paths or clearance of an efficient compressor is insufficient to relieve trapped fluid thus causing high compression forces in the formed trap which is reducing in volume. This condition is intensified when the trapped fluid contains an amount of liquid or other incompressible matter causing the forces within the trap to rise to extreme levels which tend to destroy the compressor or components thereof. Of primary concern are the seal lines created by crest surfaces 35 and 45 with flank surface 43 and arcuate wall 34, respectively. When such seal lines extend to the outlet ends of rotors 30 and 40, a trap pocket is formed. To prevent forming such traps, the present invention contemplates profiling one of the seal forming surfaces of each trap portion which removes portions of one of the rotors to space each meshing profiled surface from the adjacent seal forming surface and create an escape path therebetween without weakening the profiled rotor. In accordance with the invention, this can be accomplished in various ways.

Referring now to FIGURE 2, a main or male rotor 50 is derived by modifying the rotor 40 of the compressor of FIGURE 1 in accordance with the invention. The modified rotor 50 is mounted on the shaft 51 and has a pair of diametrically opposed helically extending lobes 52. Each lobe 52 has leading and trailing flank surfaces 53 and 54, respectively, intersecting to form the lobe crest edge surface 55. The outlet end of the leading flank surface 53 of each lobe 52 has a bevel 56 or is profiled angularly, increasing in depth toward the rotor end surface. As the depth of the bevel 56 increases, the width thereof also increase but is limited at its maximum to the surface between the lobe crest edge surface 55 and the root of the lobe 52.

By referring to FIGURES 3 to 6, it will be seen that as the outlet end of a lobe 52 of rotor 50 commences to progressively mesh with a groove 33 of rotor 30, the lobe crest edge surface 55 sealingly engages the groove surface 34 and moves therealong from the trailing crest surface 36 to the leading crest surface 35 thereof. Simultaneously, the leading crest surface 35 approaches the root of lobe 52 and moves along the leading flank surface 53. However, the terminal portion of the flank surface 53 has the bevel 56 that is spaced from crest edge surface 35 and provides an escape path 57, therebetween, for the volume of the groove 33 between the crest edge surfaces 35 and 55, to the low pressure side of the compressor or the side of chamber 21 connected to the inlet 22. The volume of groove 33 vented by the escape path 57 is normally the formed trap pocket.

Referring now to FIGURES 7 to 10, corresponding to FIGURES 3 to 6, a further modified main rotor 60 rotatable on a shaft 61 is shown in various stages of mesh with gate rotor 30. Main rotor 60 is derived by profiling or providing a shallow bevel 66 to the leading flank surface 63 of each lobe 62, which in this instance, removes the terminal portion of the lobe crest surface 65. Each crest surface 65 is formed by the intersection of a leading and trailing flank surface 63 and 64. As the terminal portion of a lobe 62 of rotor 60 commences to mesh with a groove 33 of the gate rotor 30, the leading gate rotor crest surface 35 sealingly engages the leading

flank surface 63, but the profiling 66 is spaced from surface 34 to provide an escape path 67 to the low side of the compressor or to the side of chamber 21 connected to inlet 22. As the rotors 30 and 60 continue to rotate, profile 66 adjacent the leading crest edge 35 advances toward the outlet end of rotor 60. It should be understood that the bevel 66 starts only as the crest edge surface 65 closes the forming trap from the outlet 23 or is selected so that the bevel cut does not disturb the seal which otherwise must at all times exist.

The requirement for the angle of the bevel 66 must be such that the minimum restricted portion 69 of the escape passage 67, as indicated in FIGURE 11, which leads from the forming trap in a groove 33 to the low pressure side of the compressor is formed by the remaining trailing crest edge of bevel 66 of the main rotor 60 and the wall 34 of the groove 33 of the mating gate rotor 30, when the inlet end of said crest edge is first about to emerge with the rotors 30 and 60 angularly positioned between the positions of FIGURES 11 and 12. These relationships defining limits of escape path 67 are shown at outlet end in FIGURE 13. Thus, the escape path 67 is generally triangular as in FIGURE 11, with the widest point or base of the triangle at the intersection of the bores 24 and 25 at the inlet side of chamber 21. Said triangle then tapers to a point or apex 68, situated where the helical path of the crest 65 of the main rotor 60 is midway in the helical groove 33 of the mating gate rotor 30.

It will be realized, as the trailing crest edge of bevel 66 at the outlet end of rotor 60 passes beyond a point midway in the groove 33 the outlet end of the mating gate rotor 30, the escape path of passage 59 begins to shorten from the apex 68 toward the base 69, while the angle of the escape path remains constant, thus maintaining an escape path, at the base of the triangle, having at all times sufficient area for the evacuation of the trapped fluid as shown through the successive FIGURES 11, 12 and 13.

While the foregoing is directed to alleviating or venting a forming trap by profiling a main rotor, the gate rotor 30 may be profiled in accordance with the invention. As shown in FIGURE 14, a gate rotor 30 of FIGURE 1 is modified to provide gate rotor 70 having a shaft 71 and an outer periphery 72. Rotor 70 has four helically extending grooves 73 in the periphery 72 formed by arcuate walls 74, generated by the crest edge surfaces 45 of main rotor 40, each terminating in leading and trailing groove crest edge surfaces 75 and 76 which correspond to the respective surfaces 35 and 36 of rotor 30. The terminal or outlet ends of the leading crest edge surfaces 75 are removed by profiling or have bevelling 77.

By referring to FIGURES 15 to 18, when a lobe 42 moves into mesh with a groove 73, the lobe crest edge surface 75 sealingly engages and travels along the groove surface 74. Simultaneously, the leading crest edge surface 75 sealingly engages and travels along the leading flank surface 43. When the mesh approaches the terminal stage, the profiling or bevel 77 approaches the surface 43 but is always spaced therefrom to provide an escape path 78 to prevent formation of a trap pocket.

Therefore, in accordance with the invention the rotors of an axial type compressor form running seals with the compressor chamber. The rotors have meshing helical threads with adjacent surfaces forming at least two spaced seal lines along the mesh. The terminal mesh at the outlet ends of the rotors tend to form fluid traps or trap pockets which are vented by an escape path or are prevented from fully forming by terminal profiling to remove all of one of the seal forming surfaces.

Although several embodiments of the invention have been illustrated and described in detail, it is to be understood that the invention is not limited thereto. Various changes may also be made in the design and arrangement of the parts without departing from the spirit and scope of the invention as will now be understood by those skilled in the art.

We claim:

1. A compressor comprising:
(a) a casing having a chamber with axially spaced walls for closing the ends thereof;
(b) a pair of rotors disposed in said chamber between the end walls;
(c) said chamber having an inlet and an outlet axially spaced from one another at opposite ends of the chamber and being disposed on opposite sides of a plane through the axes of rotation of both rotors;
(d) said rotors having helical lobes and grooves meshing with one another and operating to cyclically define pressure pockets being formed at the inlet end of the chamber which move progressively axially to the outlet end thereof;
(e) each of said pockets communicating with the inlet when formed and increasing in volume during such communication to receive fluid, sequentially being blocked from the inlet and reducing in volume thereafter before communication with the outlet to compress the fluid received then communicating with the outlet to discharge the compressed fluid;
(f) each of said lobes have a leading flank surface and a trailing flank surface intersecting to provide a crest edge surface;
(g) each of said grooves being defined by an arcuate surface generated entirely by the meshing lobe crest edge surfaces and terminating in a crest edge surface that generates the meshing lobe leading flank surfaces;
(h) said crest edge surfaces of meshing lobes and grooves cooperating to form seal lines with the surfaces they generate spaced by a formed pocket of varying volume defined by the lobe and groove between the seal lines;
(i) said formed pockets tending to form fluid traps when said lobes and grooves are in mesh at the outlet ends of said rotors and the formed pockets are closed to the compressor outlet after discharge; and
(j) the outlet end of one of said rotors being bevelled removing the outlet ends of all of one of said cooperating surfaces forming said seal lines to provide escape paths to the compressor inlet for fluid from said formed pockets when such traps are formed after discharge to relieve fluid trapped therein.

2. A compressor comprising:
(a) a casing having a chamber with axially spaced walls for closing the ends thereof;
(b) a pair of rotors disposed in said chamber between the end walls;
(c) said chamber having an inlet and an outlet axially spaced from one another at opposite ends of the chamber and being disposed on opposite sides of a plane through the axes of rotation of both rotors;
(d) said rotors having helical lobes and grooves meshing with one another and operating to cyclically define pressure pockets being formed at the inlet end of the chamber which move progressively axially to the outlet end thereof;
(e) each of said pockets communicating with the inlet when formed and increasing in volume during such communication to receive fluid, sequentially being blocked from the inlet and reducing in volume thereafter before communication with the outlet to compress the fluid received then communicating with the outlet to discharge the compressed fluid;
(f) each of said lobes having a leading flank surface and a trailing flank surface intersecting to provide a crest edge surface;
(g) each of said grooves being defined by an arcuate surface generated entirely by the meshing lobe crest edge surfaces and terminating in a crest edge sur-

face that generates the meshing lobe leading flank surfaces;

(*h*) said crest edge surfaces of meshing lobes and grooves cooperating to form seal lines with the surfaces they generate spaced by a formed pocket of varying volume defined by the lobe and groove between the seal lines;

(*i*) said formed pockets tending to form fluid traps when said lobes and grooves are in mesh at the outlet ends of said rotors and the formed pockets are closed to the compressor outlet after discharge; and

(*j*) the outlet ends of the lobes being bevelled between the lobe roots and lobe crest edge surfaces removing the outlet ends of the leading flank surfaces from the groove crest edge surfaces to provide escape paths to the compressor inlet for fluid from the traps formed by the grooves when such grooves and lobes are in mesh at the outlet ends of the rotors after discharge.

3. A compressor comprising:

(*a*) a casing having a chamber with axially spaced walls for closing the ends thereof;

(*b*) a pair of rotors disposed in said chamber between the end walls;

(*c*) said chamber having an inlet and an outlet axially spaced from one another at opposite ends of the chamber and being disposed on opposite sides of a plane through the axes of rotation of both rotors;

(*d*) said rotors having helical lobes and grooves meshing with one another and operating to cyclically define pressure pockets being formed at the inlet end of the chamber which move progressively axially to the outlet end thereof;

(*e*) each of said pockets communicating with the inlet when formed and increasing in volume during such communication to receive fluid, sequentially being blocked from the inlet and reducing in volume thereafter before communication with the outlet to compress the fluid received then communicating with the outlet to discharge the compressed fluid;

(*f*) each of said lobes having a leading flank surface and a trailing flank surface intersecting to provide a crest edge surface;

(*g*) each of said grooves being defined by an arcuate surface generated entirely by the meshing lobe crest edge surfaces and terminating in a crest edge surface that generates the meshing lobe leading flank surfaces;

(*h*) said crest edge surfaces of meshing lobes and grooves cooperating to form seal lines with the surfaces they generate spaced by a formed pocket of varying volume defined by the meshing lobe and groove between the seal lines;

(*i*) said formed pockets tending to form fluid traps when said lobes and grooves are in mesh at the outlet ends of said rotors and the formed pockets are closed to the compressor outlet after discharge; and

(*j*) the outlet ends of the lobe being bevelled removing the outlet end of the lobe crest edge surfaces from the arcuate groove surfaces to provide escape paths to the compressor inlet for fluid from the traps formed by the grooves when such grooves and lobes are in mesh at the outlet ends of the rotors after discharge.

4. A compressor comprising:

(*a*) a casing having a chamber with axially spaced walls for closing the ends thereof;

(*b*) a pair of rotors disposed in said chamber between the end walls;

(*c*) said chamber having an inlet and an outlet axially spaced from one another at opposite ends of the chamber and being disposed on opposite sides of a plane through the axes of rotation of both rotors;

(*d*) said rotors having helical lobes and grooves meshing with one another and operating to cyclically define pressure pockets being formed at the inlet end of the chamber which move progressively axially to the outlet end thereof;

(*e*) each of said pockets communicating with the inlet when formed and increasing in volume during such communication to receive fluid, sequentially being blocked from the inlet and reducing in volume thereafter before communication with the outlet to compress the fluid received then communicating with the outlet to discharge the compressed fluid;

(*f*) each of said lobes having a leading flank surface and a trailing flank surface intersecting to provide a crest edge surface;

(*g*) each of said grooves being defined by an arcuate surface generated entirely by the meshing lobe crest edge surfaces and terminating in a crest edge surface that generates the meshing lobe leading flank surfaces;

(*h*) said crest edge surfaces of meshing lobes and grooves cooperating to form seal lines with the surfaces they generate spaced by a formed pocket of varying volume defined by the lobe and groove between the seal lines;

(*i*) said formed pockets tending to form fluid traps when said lobes and grooves are in mesh at the outlet ends of said rotors and the formed pockets are closed to the compressor outlet after discharge; and

(*j*) the outlet end of the rotor with the grooves being bevelled removing the outlet ends of the groove crest edge surfaces from the leading flank surfaces to provide an escape path to the compressor inlet for fluid from the traps formed by the grooves when such grooves and lobes are in mesh at the outlet ends of the rotors after discharge.

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