Aug. 25, 1959 J. E. WHITFIELD 2,901,164

GENERATED ROTOR FORM

Original Filed Feb. 9, 1950 5 Sheets-Sheet 1

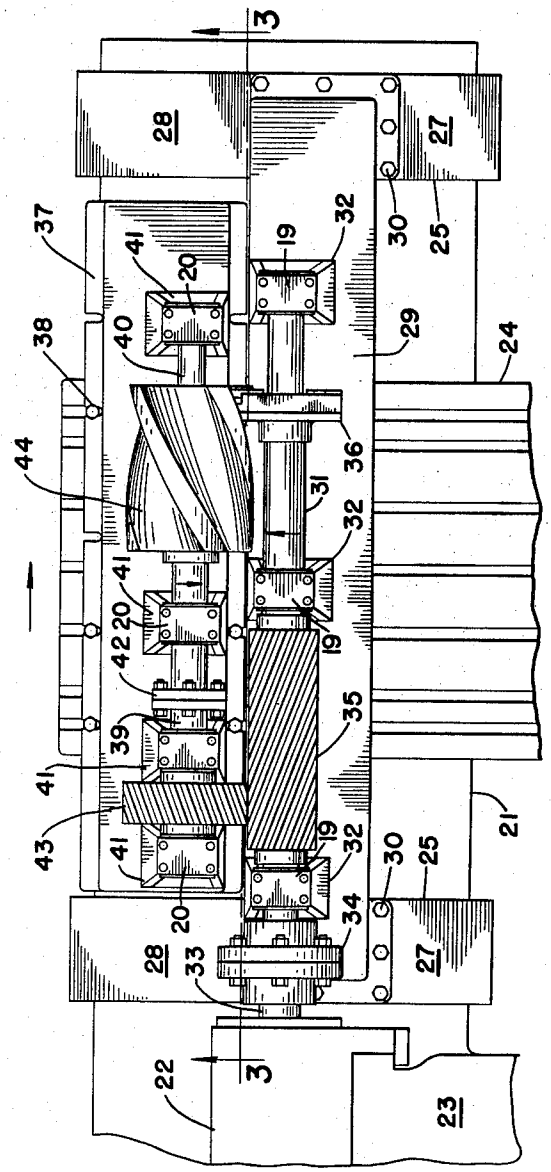


FIG. 1

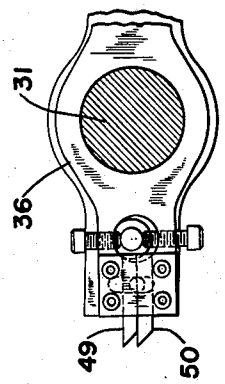


FIG. 6

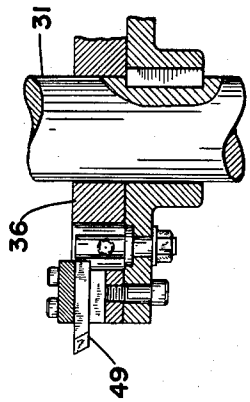


FIG. 5

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GENERATED ROTOR FORM

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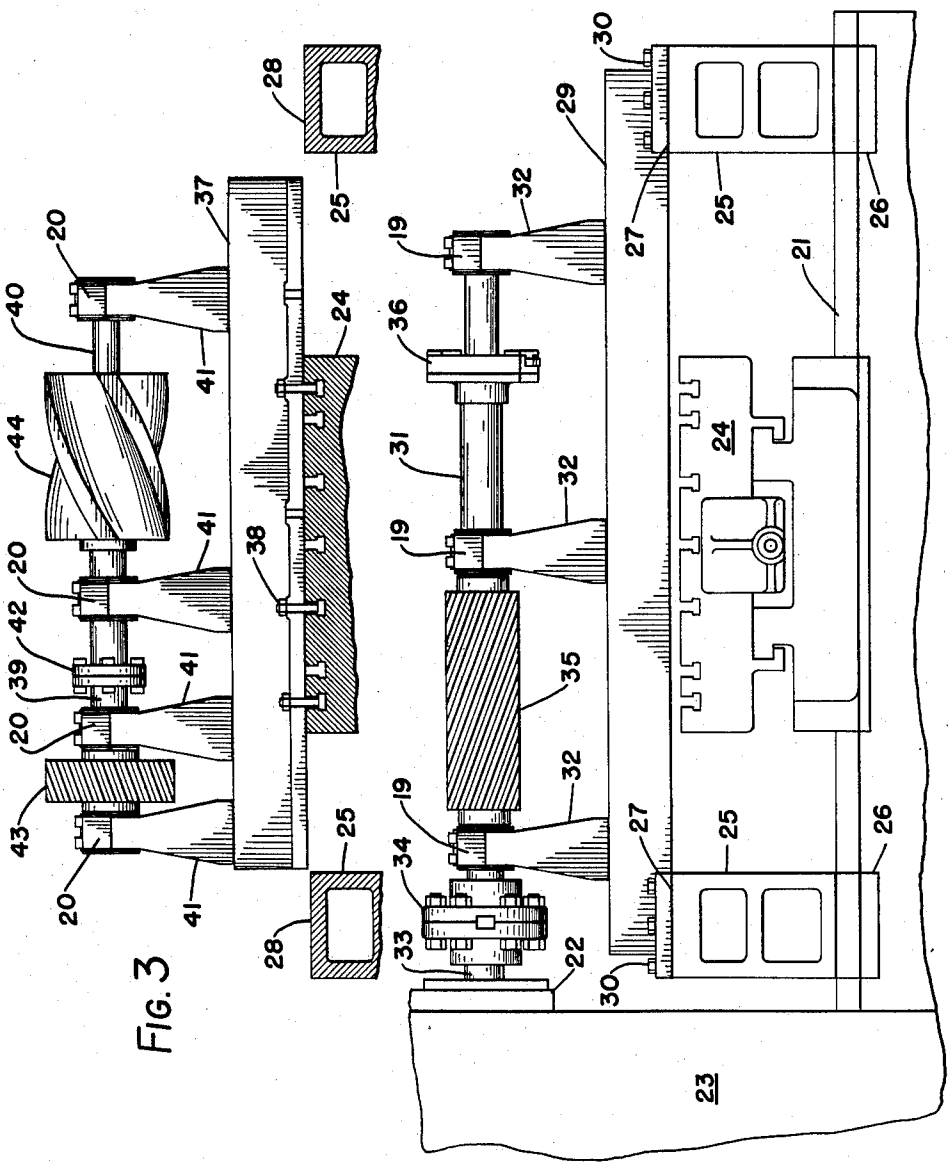


FIG. 3

FIG. 2

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GENERATED ROTOR FORM

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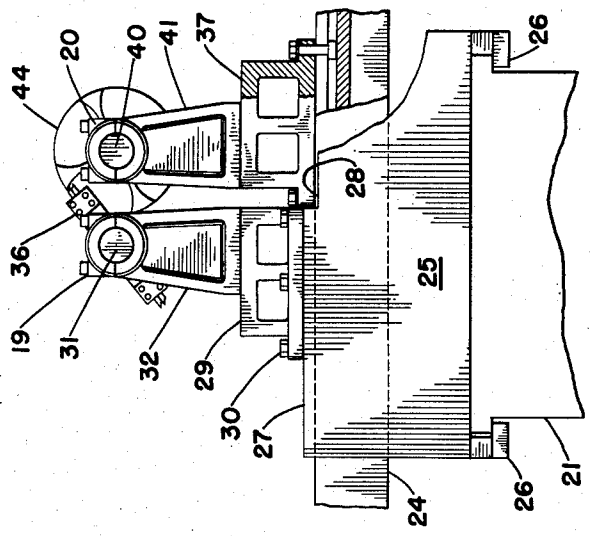


FIG. 4

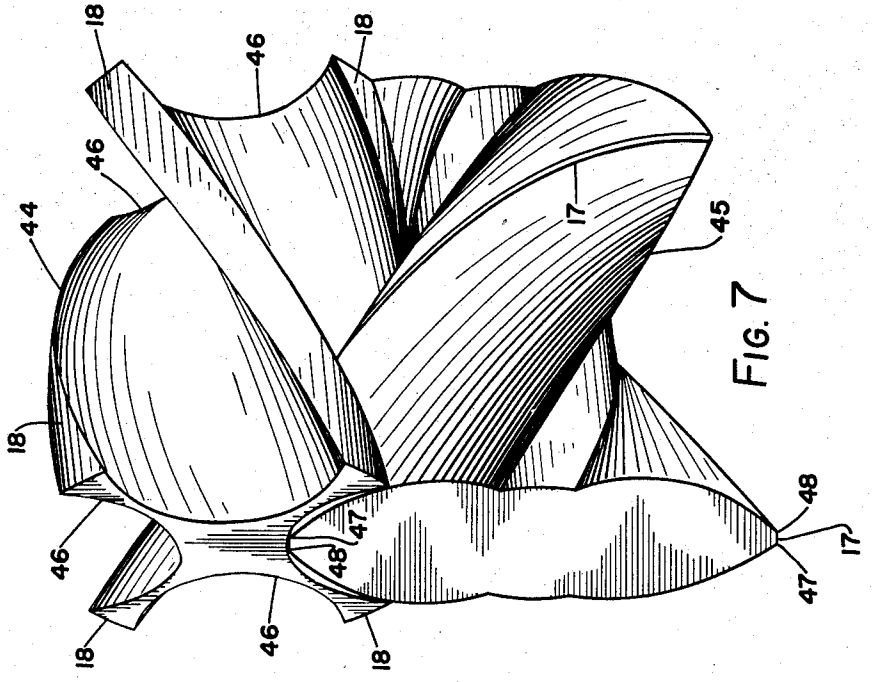


FIG. 7

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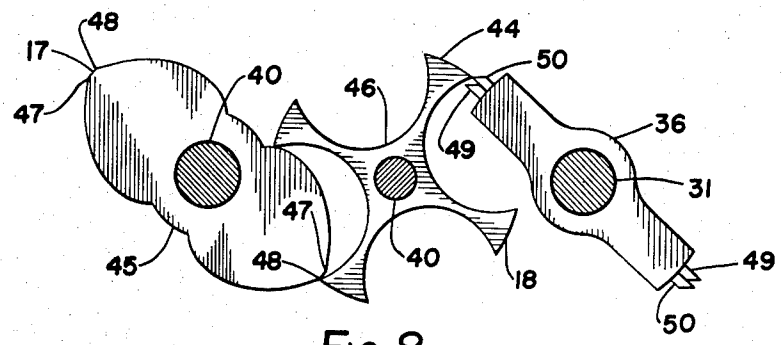


FIG. 8

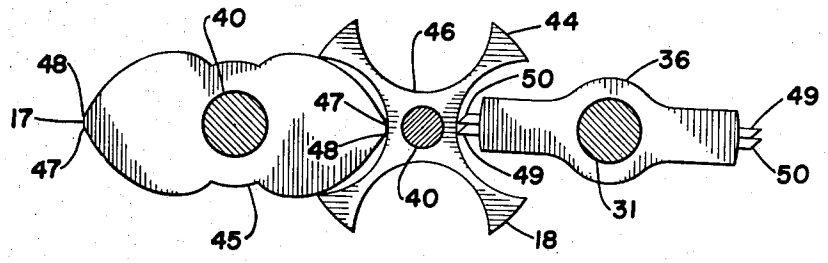


FIG. 9

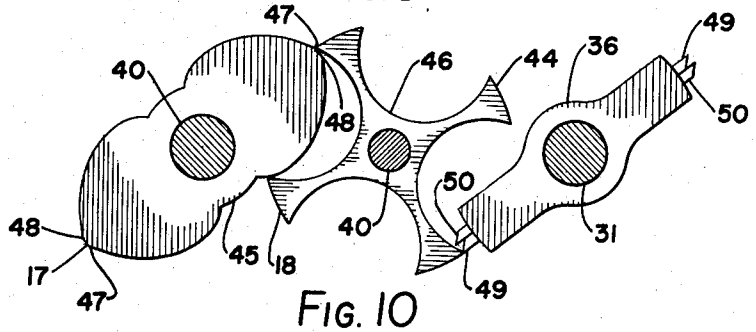


FIG. 10

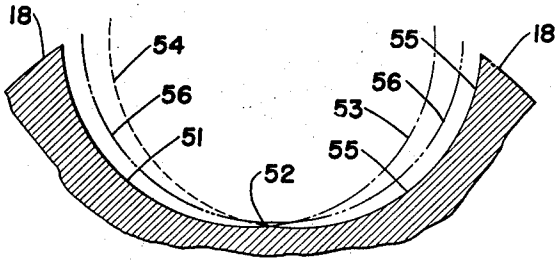


FIG. 11

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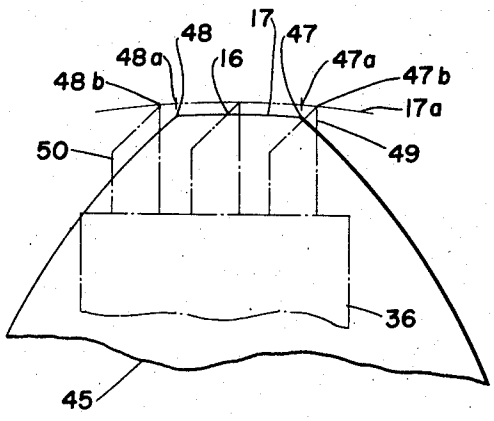
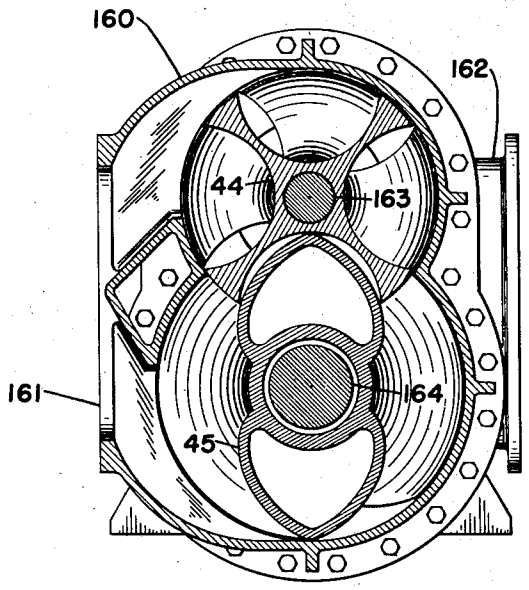


FIG. 12



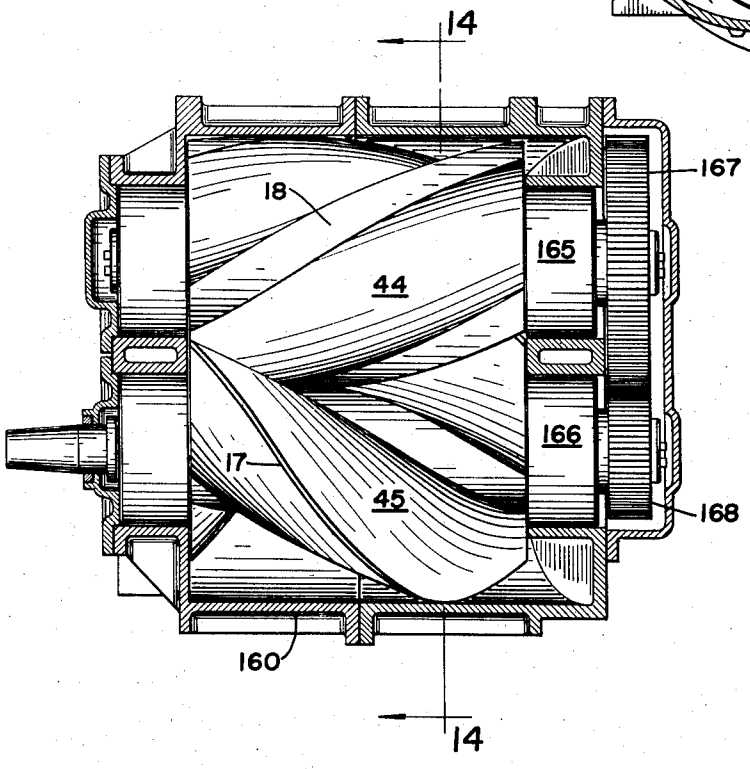


FIG. 13

FIG. 14

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United States Patent Office 2,901,164 Patented Aug. 25, 1959

2,901,164

GENERATED ROTOR FORM

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Original application February 9, 1950, Serial No. 143,259, now Patent No. 2,792,763, dated May 21, 1957. Divided and this application March 18, 1957, Serial No. 646,849

2 Claims. (Cl. 230—143)

This invention relates to improvements in rotors of a blower, compressor and the like such as described, for example, in my U.S. Patent No. 2,287,716.

Axial flow fluid devices of the type to which the said patent is predicated are provided with complementary intermeshing rotary screw members commonly referred to as the main or male rotor and the gate or female rotor, the former generally having a fully addendum thread and the latter a fully dedendum thread. The main rotor preferably has two lobes and the gate rotor four threads forming troughs or grooves. Other combinations of lobes and troughs may, however, be employed.

These rotors have symmetrical generated thread forms, the curved flanks of the lobes of the main rotor being described by the continuous crest edges of the threads of the gate rotor and the curved flanks of the troughs of the gate rotor being described by the continuous crest edges of the lobes of the main rotor.

The main object of the invention is to provide a novel gate rotor having its generated trough contour formed to provide between the generated flanks of the gate rotor trough and the generated flanks of the meshing main rotor threads a tapered clearance extending from the crest edges of the gate rotor to the bottom of the rotor trough.

Other objects and advantages of the invention will become apparent from the following description when read in connection with the accompanying drawings, in which

Figure 1 is a fragmentary plan view of a boring mill adapted for cutting a gate rotor;

Figure 2 is a fragmentary side elevation of the structure shown in Figure 1 with the rotor carrying support and brackets removed;

Figure 3 is a section taken on the line 3—3 of Figure 1;

Figure 4 is a fragmentary end elevation of the structure shown in Figure 1, viewed from the right, with parts broken away and shown in section;

Figure 5 is a fragmentary sectional view taken through the boring head;

Figure 6 is a fragmentary side elevation of the boring head and cutting tools showing the cutting tool positioning means;

Figure 7 is a view in perspective of the gate rotor and main rotor in mesh;

Figure 8 is a diagrammatic view illustrating the relative positions of the cutting tool and gate rotor blank at the beginning of a generating cut, the main rotor also being shown to illustrate how the rotation of the cutting tool simulates the action of the main rotor while the gate rotor is being generated by the cutting tool;

Figure 9 is a view similar to Figure 8 showing the cutting tool in the center of a generating cut;

Figure 10 is a view similar to Figure 8 showing the cutting tool nearing the end of a generating cut;

Figure 11 is an exaggerated view of the contour of the trough of the gate rotor, showing the paths of the cutting edges of the tools in forming a generated gate rotor

trough, and the path of the crest edges of a mating main rotor showing a tapered clearance between the crest edges of the main rotor and the flanks of the gate rotor troughs;

Figure 12 is an enlarged fragmentary diagrammatic view of a main rotor showing the relation of the cutting tools with respect to the crest edge of the main rotor for generating the trough of a mating gate rotor, the relation of the points of the cutting tools with respect to the crest edge of the main rotor for obtaining desired clearances between the gate rotor and the main rotor being exaggerated;

Figure 13 is a longitudinal vertical central section through a blower housing with the rotors assembled therein and shown in elevation; and

Figure 14 is a sectional view taken on the line 14—14 of Figure 13.

Referring to the drawings, Figures 1 to 4 inclusive show the novel rotor machining fixture attached to a horizontal boring mill having a bed portion 21, a head stock 22, a head stock supporting column 23 and a table 24 adapted for longitudinal movement along the bed portion 21. The mechanism for longitudinally moving the table 24 either in increments or continuously, representing the feed of the work to be machined, is conventional and therefore not shown and the rate of feed may be varied in any known manner. Cross supports 25 are clamped to ways formed on the bed portion 21 with clamp plates 26. The cross supports 25 are formed with top surfaces 27 and 28, the top surfaces 27 being higher than the top surfaces 28. The top surfaces 27 of the cross supports 25 are above the level of the top of the movable table 24, and the top surfaces 28 of the cross supports 25 are below the level of the top of the movable table 24.

A support member 29 is fastened on the top surfaces 27 of cross supports 25 with bolts 30 and clears the top of the movable table 24 as best shown in Figure 2. A boring bar or shaft 31 is carried over the member 29 on brackets 32 secured in any suitable manner on the member 29 and is connected to a drive spindle 33 in the boring head 22 by a coupling 34. Mounted on the boring bar 31 is a boring head 36 and a helical pinion 35, the latter having the same helix angle and opposite hand as the rotor threads desired to be cut.

Another support member 37 is carried on the movable table 24 and is secured to the table with T-bolts 38. Driven shaft 39 and shaft or arbor 40, connected together by a coupling 42, are carried over the member 37 on brackets 41 secured in any suitable manner on the member 37. Mounted on shaft 39 is a helical gear 43 adapted to mesh with the helical pinion 35 on the boring bar 31. The helical gear 43 has the same helix angle and is of the same hand as the rotor threads to be cut. Arbor 40 is formed to receive a gate rotor blank 44 arranged to rotate in timed relation with respect to rotation of the boring head 36 as hereinafter explained. The brackets 32 and 41 have removable caps 19 and 20, respectively, to permit removal of the boring bar 31, driven shaft 39 and arbor 40 for changing helical gears and receiving rotor blanks for machining.

One form of rotor which this fixture is adapted to machine is the gate rotor 44 shown with its mating main rotor 45 in Figure 7. The general contour of the troughs 46 in the gate rotor 44 is determined or generated by the path followed by the crest edges 47 and 48 on the main rotor 45 as the rotors rotate in timed relation. Actually the contour of the troughs 46 of the rotor 44 varies from a true generation by the crest edges 47 and 48 to provide necessary running clearance between the perimetral surface or crest 17 of the main rotor and the flanks of the troughs 46 of the gate rotor. Preferably, though not necessarily, the contour of the troughs 46 of

the rotor **44** is further modified from a true generation by the crest edges **47** and **48** to provide a gradually expanding clearance between the crest **17** of the main rotor **45** and the flanks of the troughs **46** of the gate rotor **44** extending from the bottom of the troughs to the crests **18** to allow for the torsional resilience at the timing gear end of the gate and main rotor shafts, backlash in the timing gears and any other distortions encountered in the operation of a blower or pump comprising helical intermeshing rotors such as shown in Figures 13 and 14. The gate rotor **44** and the means and method for forming it will be hereinafter described in greater detail.

Referring specifically to Figures 13 and 14, the housing **160** for the meshing rotors **44** and **45** is provided at diagonally opposite ends with a fluid inlet port **161** and a fluid outlet port **162**. One end of the shafts **163** and **164** of the rotors **44** and **45**, respectively, extend beyond their bearings **165** and **166**, respectively, and have the timing gears **167** and **168**, respectively, secured thereto, the ratios of which are selected to maintain the gate rotor **44** and the main rotor **45** in their proper timed relation. In the present instance the gear ratio shown is two to one.

The largest amount of distortion takes place after the main rotor and the gate rotor pockets are closed to the inlet port and when the compression of the fluid trapped in said pockets has reached its maximum before the pockets open to the discharge port. The forces exerted against the pressure of the fluid in said pockets by the driving means causes the rotor shafts to twist slightly between the ends of the rotors and the timing gears, in consequence of which the forward flanks of the main rotor timing gear teeth press against the rear flanks of the gate rotor timing gear teeth. When the rotor pockets open to the outlet port and the pressurized fluid is exhausted through said port the rotor shafts return to their normal condition and the rear flanks of the main rotor timing gear teeth snap back against the forward flanks of the gate rotor timing gear teeth. This action of the rotor shafts and timing gears during the compression and exhausting cycles of the blower causes the gate rotor to be slightly out of its timed relation with the main rotor and provision must be made in the clearances between the troughs of the gate rotor and the crests of the main rotor to prevent any contact between the two rotors during these cycles.

The distortions caused by the torsional resilience and the gear backlash is preferably provided for by having a gradually expanding clearance between the crest **17** of the main rotor **45** and the flanks of the trough **46** of the gate rotor **44**, with the maximum clearance at the top of the trough and the minimum running clearance at the bottom of the trough. This is best shown in an exaggerated section of a trough in the gate rotor in Figure 11 in which the trough is defined by the lines **51** and **55** and the path followed by the crest **17** of the main rotor is defined by the double dot and dash lines **56**.

Torsional distortion of the rotor shafts and backlash in the timing gears does not affect the clearance between the crest of the main rotor and the bottom of the trough of the gate rotor when in juxtaposition as shown in Figure 9 and therefore the troughs of the gate rotor are preferably formed, as later described, to provided a minimum running clearance between the crests of the main rotor and the bottom of the gate rotor troughs. Such torsional distortion and backlash does, however, effect a progressively greater variance in clearance between the crest **17** of the main rotor and the trough of the gate rotor outwardly along the flank of the gate rotor trough from the bottom of the trough to its crest **18**, and the flanks of the gate rotor trough are therefore preferably formed to provide a progressively greater clearance between the crest of the main rotor and the flanks of the gate rotor trough outwardly along the said flanks from the bottom of the trough to its crests **18**. For example, the gate rotor may be formed to provide a clearance of .005 between the crest of the main rotor and the bottom of the gate rotor trough increasing to .010 between the crest of the main rotor and the flank of the gate rotor trough adjacent the crests **18**.

The importance of the tapered clearance thus provided by the contour of the gate rotor trough lies in the fact that clearance between the crest of the main rotor and the gate rotor trough varies as the necessity for clearance varies due to the aforesaid distortion, and a minimum practical clearance is provided, resulting in a minimum of leakage of fluid and thereby providing a more efficient blower.

The machining of a groove that will provide the aforesaid tapered clearance is accomplished by setting the tool bits **49** and **50** in the boring head **36** with the distance between the center of the shaft **31** and the cutting points of the tool bits **49** and **50** being equal to the distance between the center of the main rotor **45** and its crest edges **47** and **48**, plus the desired minimum running clearance between the main rotor crest and the bottom of the gate rotor trough, and making the distance between the cutting edges of the tool bits **49** and **50** slightly greater than the distance between crest edges **47** and **48** of the main rotor. This adjustment of the distance between the edges of the tool bits **49** and **50** controls the amount of the tapered clearance between the main rotor and the gate rotor.

The relation of the tool bits **49** and **50**, for cutting the gate rotor trough, with respect to the main rotor that is intended to mesh with the gate rotor is best illustrated in the exaggerated diagrammatic view, designated as Figure 12. The points of the tool bits **49** and **50** are shown extending a radial distance outward beyond the crest **17** of the main rotor **45** in order to provide a running clearance between the crest of the main rotor and the trough of the gate rotor. The points of the tool bits **49** and **50** are also clearly shown to be spread farther apart than the crest edges **47** and **48** of the main rotor whereby the gate rotor trough cut by the tool bits **49** and **50** provides the aforesaid tapered clearance when the main rotor is arranged in meshing engagement with the gate rotor. Additional cutting tools may be disposed between the cutting bits **49** and **50** if the distance between them permits, one such cutting tool being shown at **16** in Figure 12.

Enlarging somewhat on the above, assuming the tool bits **49** and **50** are extended a radial distance outward beyond the crest **17** to the concentric arc **17*a*** and spaced apart a distance equal to the distance between the crest edges **47** and **48**, represented in Figure 12 by the points **47*a*** and **48*a***. In this event, because of the angularity of the tool with respect to the surface being cut, the depth of the cut will be greater at the bottom of the gate rotor trough than upwardly along the flanks of the trough. This will become apparent upon comparing Figures 8 and 9 or Figures 9 and 10.

By spacing the tool bits **49** and **50** circumferentially farther apart than the crest edges **47** and **48**, for example, at points **47*b*** and **48*b*** on the arc **17*a***, the depth of the cut at the bottom of the gate rotor trough does not change but the depth of the cut along the flanks of the trough becomes greater. Thus by altering the radial projection of the tool bits and their circumferential spacing, the gate rotor troughs may be formed to provide a desired clearance between the crest of a main rotor and the flanks as well as the bottom of the trough of a mating gate rotor.

Figures 8, 9 and 10 show the cutting tools in three positions passed through during the machining of a trough and the main rotor in like positions, the arrows indicating the direction of rotation. In Figure 8 the crest edge **48** of the main rotor is entering the trough of the gate rotor and the tool bit **50** has started its cut. Figure 9 shows the main rotor **45** with crest edges **47** and **48** in the center of the trough of the gate rotor **44** and tool

bit 50 about to finish its cut and tool bit 49 starting to cut. Figure 10 shows the crest edge 47 of the main rotor 45 leaving the trough in the gate rotor 44 and tool bit 49 finishing its cut. From these illustrations it may be seen that the path followed by the edges 47 and 48 of the main rotor 45 may be duplicated as closely as desired with the tool bits 49 and 50 in the boring head 36.

Figure 11 shows an exaggerated diagram of the path followed by the cutting edges of the tool bits 49 and 50. Tool bit 50 follows the solid line 51 and cuts to point 52 and follows dot and dash line 53 relative to the gate rotor until it leaves the trough. Tool bit 49 enters the trough and follows the dotted line 54 relative to the gate rotor until it reaches point 52 where it begins its cut and follows the solid line 55 until it leaves the trough. The generated contour of the troughs in the gate rotor may be held to a very close tolerance by controlling the distance between the axes of boring bar 31 and arbor 40, the distance between the points of the tool bits 49 and 50 and the radial extent of the tool bits.

The helix angle of the threads of the gate rotor 44 is controlled by the helix angle of the teeth on the pinion 35 on boring bar 31. Thus if the teeth on the pinion are straight, the threads formed on the rotor, as the blank is fed axially parallel with the boring bar 31, will be straight. With the helically formed teeth on the pinion 35, as shown, the same helix angle will be transferred to the threads of the rotor 44 as the blank is fed axially to the cutting tools on the boring head 36 parallel with respect to the boring bar 31 while the gear 43 and pinion 35 are in mesh.

For purpose of illustration, the drawings show mating rotors with four threads on the gate rotor and two threads on the main rotor, fixing the speed ratio of the main rotor and the gate rotor at two to one. Thus while the main rotor 45 is making two revolutions the gate rotor 44 is making one revolution. This ratio is maintained on the rotor machining fixture by having a two to one gear ratio between the helical pinion 35 and the helical gear 43 but the rotational ratio between the blank 44 and the boring head 36 is altered from the two to one gear ratio as the table 24 supporting the gear 43 and rotor blank 44 is moved to advance the gear 43 along the pinion 35 and the rotor blank 44 along the cutters to produce the helical thread form as hereinafter explained.

In operation, referring particularly to Figure 1, the rotor blank 44, on which the helical troughs are to be cut, is mounted on the armor 40. The blank may be cast oversize to the approximate shape of the rotor member and then placed on the machine for cutting. In the case of the rotor blank shown, the helix angle of the troughs selected is such that for that length of rotor the troughs extend through 90°. The pinion 35 is then chosen to agree with the helix angle of the rotor troughs to be cut and a gear 43 that will mesh with pinion 35, the gear ratio between the gear and pinion being two to one.

Let it now be assumed that the boring bar 31 carrying the helical pinion 35 and the boring head 36 is rotating in the direction of the arrow, that the shaft and arbor 39, 40, carrying the helical gear 43 and the rotor blank 44, respectively, are rotating in the direction of the arrow, and that the longitudinal movement or feed of table 24 is in the direction of the arrow, that is, from left to right.

As the table 24 moves to the right, correspondingly advancing the rotor blank 44, the tools 49, 50, will generate the profile of the flanks of the rotor trough as previously described while the helical pinion 35 develops the helical thread form thereof.

This helical thread form results from a variation in the timing of the rotor blank 44 and the tool holder 36 from the one to two gear ratio of the gear 43 and pinion 35, due to the longitudinal travel of the gear 43 along the pinion 35. It is apparent that, with the table 24 and consequently the gear 43 and blank 44 moving to the

right, and with the teeth of the gear 43 and pinion 35 cut in the direction shown, the rotational ratio of the tool holder 36 and gear blank 44 will be altered from the fixed one to two gear ratio between the gear 43 and pinion 35, so that the gear blank 44 will make a fraction more than two complete revolutions for each complete revolution of the tool holder 36. It follows that the cutter will start its cut of a particular rotor trough progressively sooner around the circumference of the blank 44 resulting in a helical thread form. The cutter must gain 90° on the rotor blank during the feeding across its length. Thus the amount that is gained over a one to two ratio depends upon the amount of feed per revolution, and the greater the feed the greater the increase in ratio. The device automatically compensates for variation in rate of feed, so that irrespective of the feed, the helix angle of the pinion 35 and the helix angle of the trough cut on the rotor blank remains the same.

If the cutting is performed while the blank is moving in the direction opposite that indicated in Figure 1, then the cutter will start its cut of a particular rotor trough progressively later around the circumference of the blank 44 since now the gear blank 44 will make a fraction less than two complete revolutions for each complete revolution of the tool holder 36, and the helical thread cut on the blank will be in the same direction as before.

Increasing or decreasing the feed speed of the table 24 relative to the rotational speed of the pinion 35 of tool holder 36 changes the rotational ratio between the rotor blank 44 and the tool holder 36, but does not alter the helix angle of the cut.

This application is a division of my co-pending application Serial No. 143,259, filed February 9, 1950, now Patent No. 2,792,763.

The lobes 45 are formed as described in my application now Patent Number 2,792,763 of which this is a division. Therein is shown apparatus for generating the side profile with respect to the troughs. Cutters are shown therein suitably mounted to correspond with the trough crest edges for turning the lobes. For purposes described therein the crest of the lobe 16 is flat and has defined edges 47 and 48.

It will be understood that the method of cutting the troughs as herein explained to produce a profile generated by the offset cutters 49 and 50, while providing clearance tapering as indicated by the line 56 of Fig. 11 under conditions of running with no discharge pressure, will give the effect of substantially no clearance under load. This is due to torsional distortion in the gate rotor. Since there is negligible distortion in a radial direction the clearance at the bottom of the gate rotor can be very little while the sides of the trough as they become more radial have greater distortion necessitating a tapering clearance as indicated by the line 56 and its relation to the faces 51 and 55.

Inasmuch as the amount of taper is only about .005 of an inch and occurs along the line of contact between the gate and main rotors it is impossible to show it in drawings other than such as indicated by Fig. 11. The actual tapering occurs along a warped line of contact such as might be imagined by reference to Fig. 13, as the contact line between rotors 44 and 45. Actually that line is not visible from any single point view.

I claim:

1. Rotary elements for use in a ported housing of an axial flow fluid device of the character described comprising a male rotor having helical lobes and a gate rotor having helical troughs mating with said lobes, said lobes having in profile sides generated with respect to said troughs and at their outermost crests a flattened face with defined edges, and said troughs having in profile a curvature generated by a point laterally offset from one of said defined edges to provide clearance between said rotors in their fully mated position greater at all points in the sides of said troughs than at the crest of the lobe.

2. Rotary elements for use in a ported housing of an

axial flow fluid device of the character described, comprising a male rotor having helical lobes and a gate rotor having helical troughs mating with said lobes, said lobes having in profile sides generated with respect to said troughs and at their outermost crest a flattened face with defined edges and said troughs having in profile a curvature generated by points each laterally offset from the respective said defined edges to provide clearance between said rotors in their fully mated position greater at all portions of the sides of said troughs than at the crest of the lobe.

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