Dec. 6, 1966 J. DUBROVIN 3,289,501

METHOD OF MACHINING A PUMP STATOR

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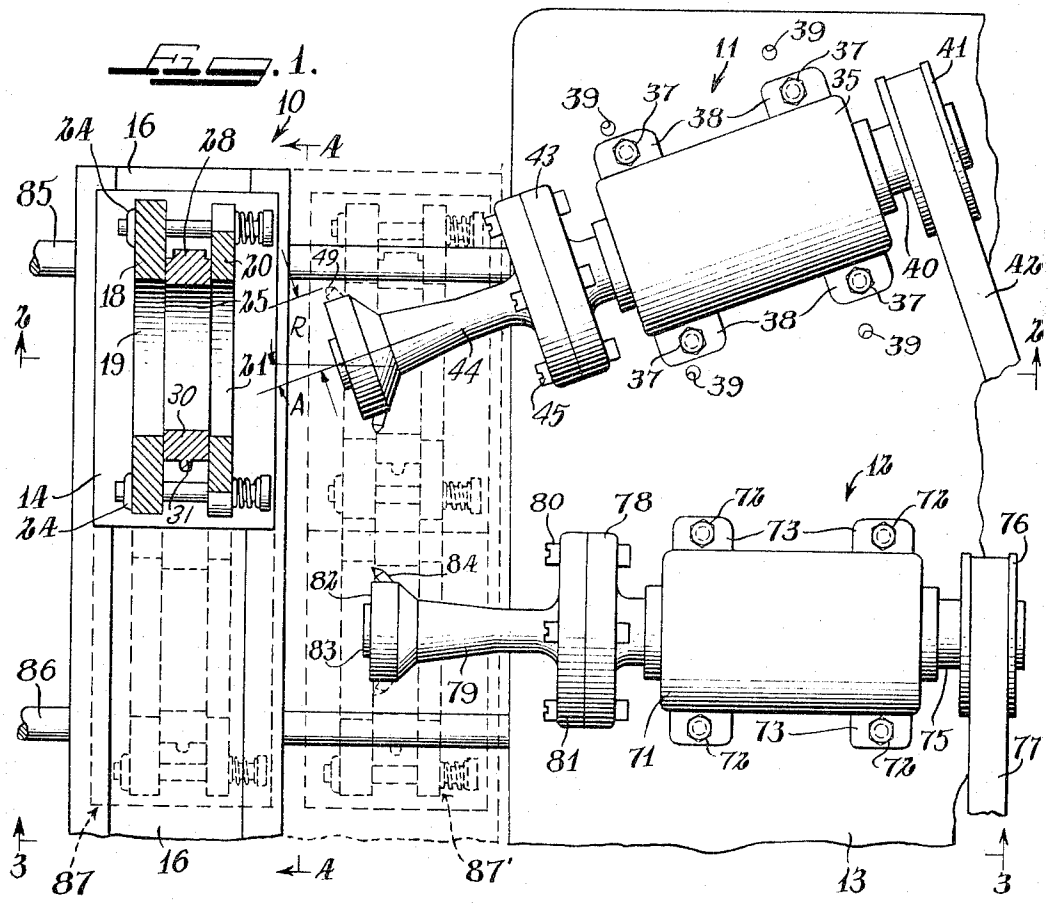


FIG. 1.

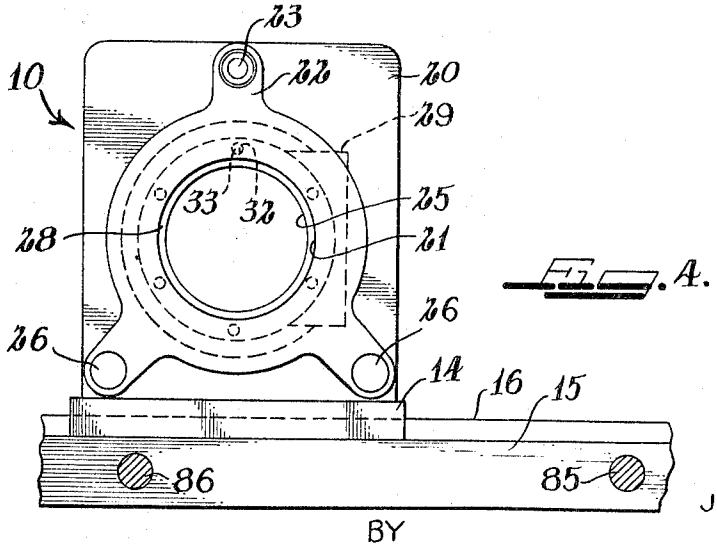


FIG. 4.

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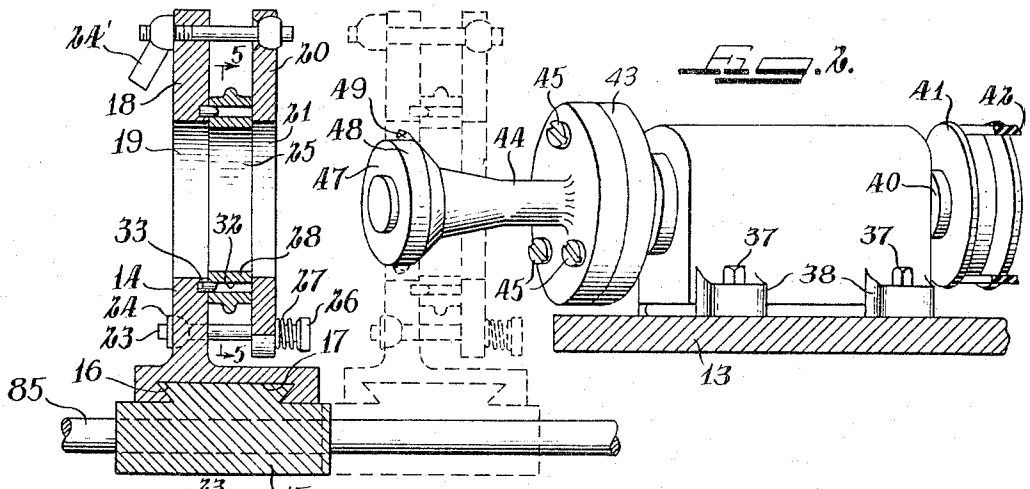


FIG. 4.

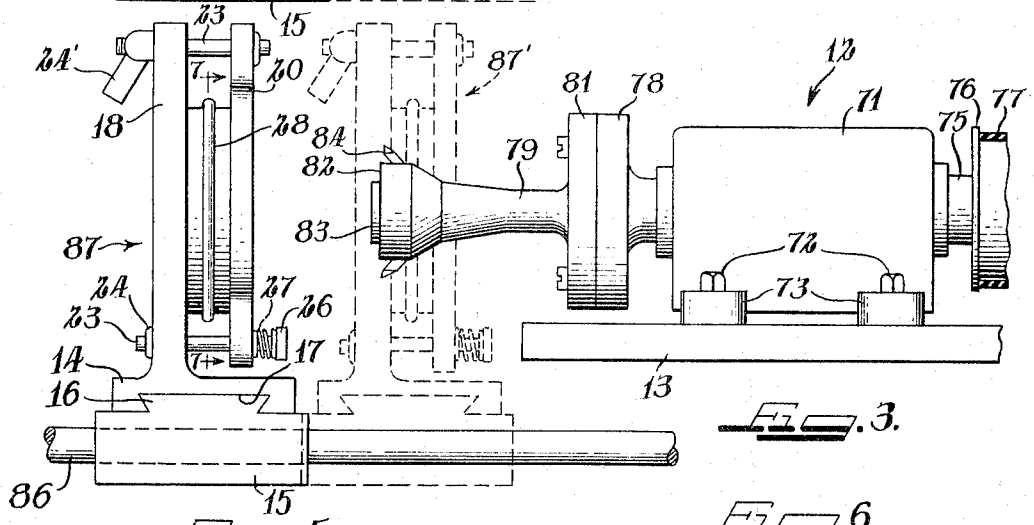


FIG. 3.

FIG. 5.

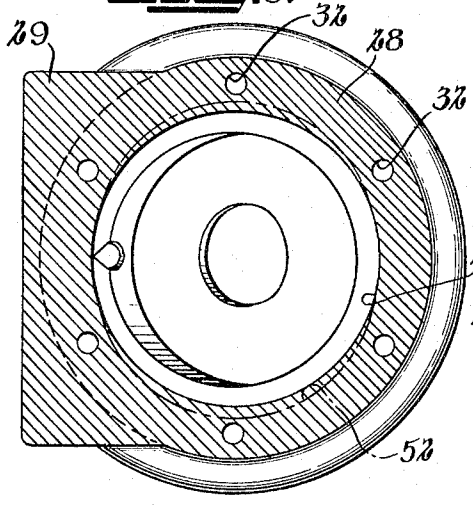
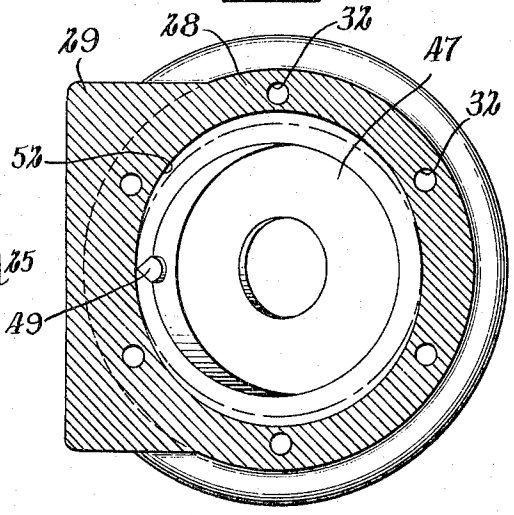


FIG. 6.



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Fig. 7.

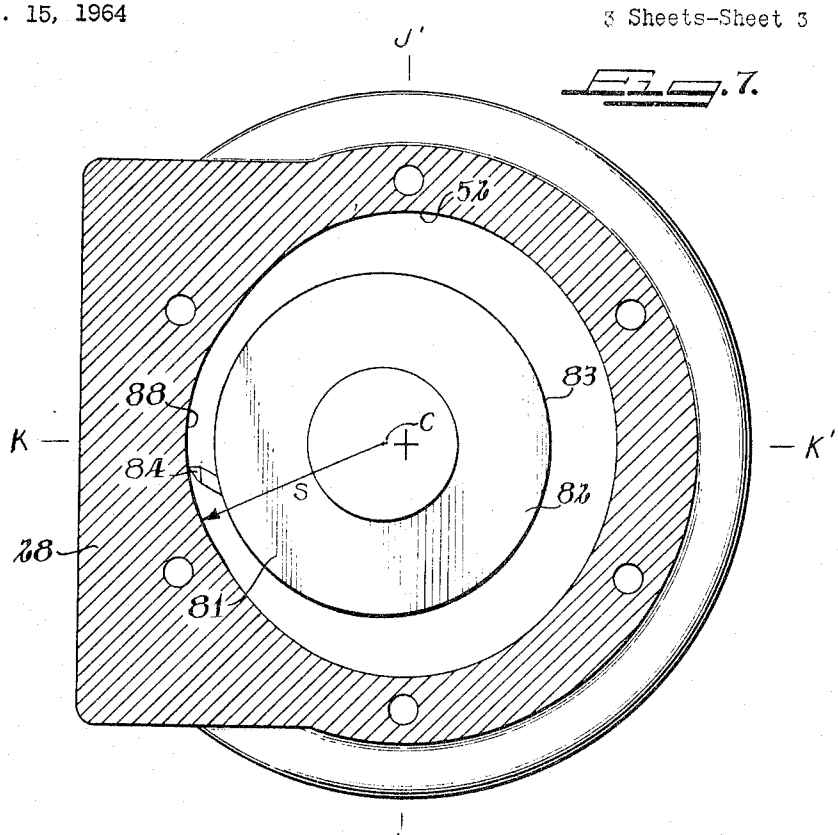
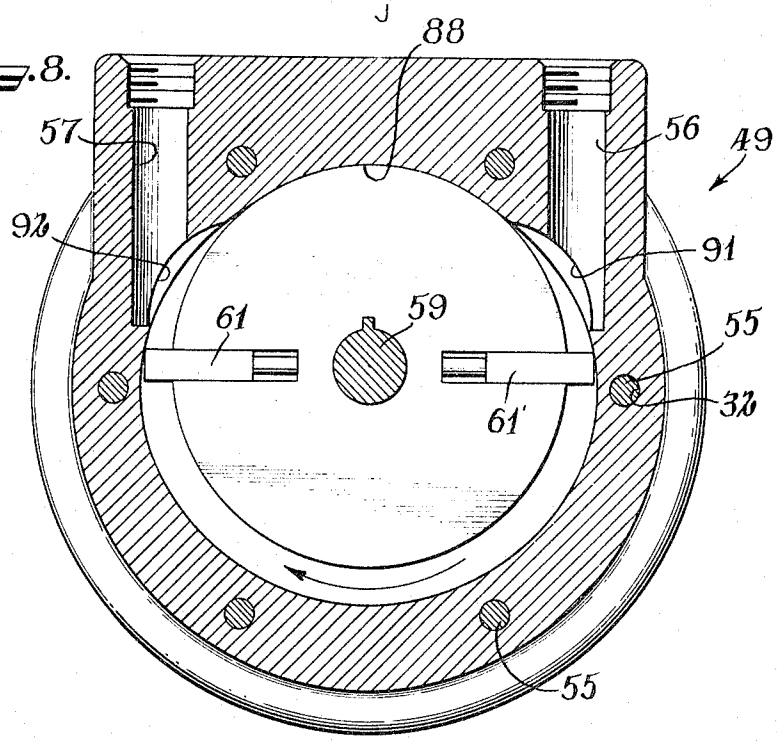


Fig. 8.



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METHOD OF MACHINING A PUMP STATOR

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2 Claims. (Cl. 77—61)

This is a continuation-in-part of application Serial No. 258,501, filed February 14, 1963 and now abandoned.

This invention relates to a new and improved method of forming an elliptical or oval-type cavity in a workpiece and thereafter accurately forming an arcuate seat in the wall along the minor or short axis in a workpiece. A new and improved device for carrying out this method also forms a part of the invention. Specifically, the method and means of the present invention has particular utility in the novel forming and shaping of a cavity in the housing or stator ring of a pump wherein it is preferred to utilize a cavity shaped as an oval or true ellipse having a circular seat formed along the wall in the area of the short or minor axis.

My copending application, Serial No. 189,369, filed April 23, 1962, now abandoned, is directed to a new and improved form of vacuum pump having an oval-shaped stator cavity in which a cylindrical rotor is received. The rotor is provided with a pair of outwardly spring urged vanes placed in running engagement with the internal surface of the cavity and movable radially inwardly of the rotor so as to pass over the arcuate seat formed between the inlet and outlet portions of the cavity. By shaping the cavity in an elliptical manner, several pump operational advantages are obtained, not only due to the enlargement of the cavity but also due to the use of an arcuate seat or seal between the inlet and outlet portions.

As set forth in my copending application alluded to above, the advantages include a reduction in vane sealing pressure outside the seat or seal area to such a degree that a material reduction in starting torque requirements in the presence of a liquid oil filled stator cavity is realized. Additionally, a substantial reduction is effected in the vane resistance to hydrostatic back pressure due to the release of spring compression. It logically follows that less frictional heat is developed as a result of the reduction of the vane pressure during rotation relative to the stator cavity, reducing the degree of lubricant volitalization as well as resistance to diffusion of pump gas, and resulting in a marked increase in conductance for greater pumping efficiency. These and other advantages are fully described in my aforementioned copending application and reference to this application is solely for the purpose of illustrating one particular use of the method and means about to be described.

Existing methods for forming cavities of the shape described above have not been completely satisfactory from the commercial standpoint since they generally involve at least two separate boring operations in addition to forming a seat. In the prior art designs, the boring tool or lathe is advanced squarely into a flat workpiece to form, in effect, overlapping circles. Following completion of the two boring operations, final shaping of the cavity was also necessary at the top and bottom wall surfaces to define the minor axis of the elliptical shape and smooth off the transition between the adjacent circles defined by the initial separate boring operation. Thereafter, the arcuate seat was formed by an additional boring or milling operation along the minor axis. Problems were encountered in accurately forming the seat at the appropriate position along the minor axis largely due to the errors arising during transfer of the workpiece from the cavity forming operation to the seat forming operation.

The present machine and method obviate the difficulty

of the prior art devices and methods as set forth above through the provision of a first tool appropriately arranged on the novel machine to form an oval or elliptical cavity in a single pass boring operation. An arcuate seat is formed along the minor axis of the ellipse through a second boring operation which is also accomplished with a high degree of accuracy. In order to attain this end, the machine includes a novel work holder which mounts the workpiece or stator of the pump for advancement to the first boring tool which forms the ellipse. Lateral translation of the work holder and workpiece to a second boring tool is effected to form the seat or seal for co-operation with a rotor member. The more important aspects of the present invention together with the detailed features of the apparatus and method of practice will be more readily understood on a consideration of the objects to be achieved and a detailed description which follows:

It is a general object of the present invention to provide a new and improved method and means for forming an elliptical-shaped cavity in a workpiece, and thereafter accurately forming an arcuate seat along the minor axis, the cavity being completely shaped in a single step material removal operation, with the seat being formed in a second step.

A further object is to provide a new and improved method of shaping the cavity in a stator member including the formation of an elliptical cavity and arcuate rotor seat.

Still another object of this invention is to provide a new and improved device of uncomplicated design and arrangement adapted for the forming of an elliptical-shaped cavity and arcuate rotor seat in a workpiece in a new and improved manner.

Still a further object of this invention is to provide a new and improved method of accurately forming a rotor seat in an elliptical cavity.

Further and fuller objects other than those specifically set forth will become apparent from the following detailed description of the invention made in conjunction with the accompanying drawings wherein:

FIG. 1 is a fragmentary partly sectioned top plan view of a device forming a part of the invention and capable of carrying out the method;

FIG. 2 is a fragmentary partly sectioned side elevational view of one boring tool assembly of the device of FIG. 1 taken generally along the lines 2—2 of FIG. 1;

FIG. 3 is a fragmentary partly sectioned side elevational view of the other boring tool of the device of FIG. 1, taken generally along the lines 3—3 of FIG. 1;

FIG. 4 is an elevational view of the workpiece holder and the workpiece forming a part of the device of FIG. 1 as viewed generally along the lines 4—4 of FIG. 1;

FIG. 5 is an enlarged vertical cross section of the workpiece taken generally along the lines 5—5 of FIG. 2;

FIG. 6 is a view similar to FIG. 5 illustrating the effect of the advancement of the cutter means within the workpiece;

FIG. 7 is an enlarged vertical section of the workpiece taken generally along the lines 7—7 in FIG. 3 and illustrating in end elevation, the cutter means of the tool in its operative position to form the rotor seat in the workpiece; and

FIG. 8 is an enlarged vertical section of a vacuum pump taken through the stator ring illustrating the use of the workpiece illustrated in the previous views.

The basic concept of the present invention resides in the forming of a cavity in a workpiece by removing material along a circular path which is angularly related to the direction of workpiece removal. On completion of the cavity forming step, the workpiece is moved to a second stage of manufacture wherein a seat is formed

along one side of the cavity. The first and second steps are performed on the workpiece while it is held in a workpiece holder adapted to shift the workpiece between stations in a single machine to obtain greatest accuracy in machining.

This concept will be described in conjunction with the forming of a pump stator cavity containing a rotor seat. The metallic material of the stator is effectively removed by a suitably arranged pair of cutter means during a two-step operation. It must be borne in mind, however, that the underlying concept of the present invention extends to the forming of an oval-shaped cavity in any suitable workpiece together with a second step to form an arcuate seat and for any desired purpose.

FIGS. 1–4 illustrate the device of the present invention which is capable of efficiently and economically forming a cavity in a pump stator in the elliptical shape with an arcuate seat formed in the position described above. This device includes a workpiece holder assembly indicated generally at **10** adapted to mount a workpiece for movement longitudinally of a pair of cutting tool assemblies **11** and **12**. Each of the tools indicated generally at **11** and **12** is supported on a common housing or platform **13** which also mounts the workpiece holder assembly **10** for movement longitudinally and laterally of the tools in a predetermined path as will be described hereinafter. The workpiece holder assembly includes a supporting platform **14** mounted for movement laterally of the tools on a guide means indicated generally at **15** and as illustrated in FIGS. 2 and 3 includes a dove tail guide **16** slidably receiving a dove tail groove **17** on the underside of the platform **14**. Obviously, any guide arrangement may be employed so long as it permits accurate movement of the workpiece, the present guide arrangement being selected to illustrate the principles of the device. An upstanding rear frame member **18** is formed integral with the base **14** and is provided with a central circular opening **19**.

A spring biased front frame member **20** is generally annular in form having a central opening **21** coextensive with the opening **19** in the rear frame member **18**. The front frame member **20** includes a plurality of circumferentially spaced radially projecting ears **22** adapted for attaching the same by means of pins **23** to the rear frame member by a locking means **24**. Three such locking members are illustrated in the embodiment shown and it is contemplated that one of the three, as shown in FIGS. 1–3, may be provided with an adjustable locking means **24'**.

Each of the pins **23** on the lowermost ears **22** project outwardly beyond the front frame member **20** and include enlarged heads **26** providing a bottoming shoulder for coil springs **27** which urge the frame member **20** resiliently against an adjacent face of a workpiece **28** clamped between the rear and front frame members **18** and **20** respectively.

The workpiece **28** illustrated in the present device constitutes a pump stator provided with an enlarged rectangular top portion **29**, a preformed circular aperture **30** located centrally thereof, and a circumferentially extending reinforcing web **31** extending around the central aperture **30**, designed to provide additional strength to the stator when provided with apertures to receive fastening means such as bolts or the like in assembly of the stator with co-operating pump parts. The apertures **32** are also useful in the workpiece assembly **10** to perform a locating function to position the workpiece securely and properly within the workholder. Dowel locator pins **33** carried on the rear face and/or front face of the workpiece assembly co-operate with the aperture **32** to insure accurate and firm positioning of the workpiece **28**.

The stator workpiece **28** is adjustably clamped between the rear and front frame members **18** and **20**, respectively, and located in proper position relative to the aligned apertures **19** and **21** by means of the dowel locating pins **33**. It is contemplated that the apertures **19** and **21** in the rear and front frame members **18** and **20** respectively will be slightly larger than the circular aperture **30** formed in the stator casting in order to expose the immediately adjacent marginal material of the stator to the tool for controllably enlarging the same into an oval or elliptical shape, and thereafter while still held in the workpiece holder, accurately forming a rotor seat in the wall of the cavity in the region bisected by the minor axis.

Referring to FIGS. 1–3, a supporting platform **13** has mounted thereon cutting tool assemblies **11** and **12**. The cutting tool assembly **11** includes a bearing housing **35** which is detachably secured by fasteners **37** extending through flange supports **38** forming a part of the bearing housing **35**. The platform **13** is provided with specially arranged apertures **39** which are adapted to receive the fasteners **37** to vary the positioning of the cutting tool assembly **35** relative to the workpiece assembly **10**.

An operating shaft **40** extends through the bearing housing **35** mounting a drive pulley **41** at one end which is driven by means of a belt **42** extending to a suitable power means such as an electric motor or the like (not shown). The other end of the shaft **40** projects outwardly of the housing **35** and is formed with an enlarged coupling head portion **43** detachably mounting cutter means **44** by means of a plurality of fasteners **45**.

The cutter means **44** is in the form of a spindle with an enlarged coupler head **46** at one end and an annular cutting head **47** at the opposite end having a generally cylindrical outer periphery **48**. A forwardly inclined cutting bit **49** is mounted for rotation on the cutting head. It is contemplated that a single cutting bit or tool **49** will be employed, however, a plurality of cutting bits may be used if circumstances dictate.

Any suitable type of cutting bit and cutting point may be used with the latter projecting substantially outwardly from the periphery **48** in a forwardly direction at a slight angle to the longitudinal axis of the cutter means **44**. FIGS. 1 and 2 illustrate multiple positions of the cutting bit **49** in broken lines for ease in understanding the operation of the device.

Also mounted on the supporting platform **13** is the cutting tool assembly **12** which includes a bearing housing **71** detachably secured to the support **13** by means of fasteners **72** extending through flange supports **73** forming a part of the bearing housing **71**. The platform **13** is provided with a plurality of apertures to receive the fasteners **72** in order to properly position the cutting tool assembly **12** to maintain the longitudinal axis thereof at right angles to the lateral travel of the workpiece assembly **10**.

An operating shaft **75** is provided with a drive pulley **76** at one end which is driven by suitable power drive means (not shown) through an endless drive belt **77** or the like. The opposite end of the shaft **75** projects outwardly of the housing **71** and is formed with an enlarged coupling head **78** detachably mounting a cutter means **79** through fasteners **80**. The cutter means **79** is in the form of a spindle, including an enlarged coupling head portion **81** attached to the shaft head portion **78** and an outwardly projecting circular cutting head **82** formed with a flat outer periphery **83** on which is positioned a radially outwardly projecting and forwardly inclined cutting bit **84**. As noted above, the cutting bit is of any suitable type and the cutting point thereof projects substantially outwardly of the periphery **83** and rotates about an axis which is parallel to the travel of the work as it moves inwardly towards the cutter head. Obviously, plural cutting tips or bits may be used in lieu of the single cutting tip **84** shown. FIGS. 1, 3 and 7 illustrate the multiple

position of the cutting tip 84 in solid and broken lines for ease of understanding the operation of the device.

Referring once again to FIG. 1, the cutting tool assemblies 11 and 12 have the cutting head portions thereof rotated about their respective longitudinal axis. The workpiece assembly 10 is advanced toward the first cutting tool assembly 11 to its final position shown in FIGS. 1 and 2 in phantom lines. As the workpiece is fed toward the cutting tool assembly, the cutting head 47 is rotated continuously causing the cutting bit 49 to effect material removal on the workpiece 28 as the two intersect. Suitable means (not shown) is provided to control the advancement of the workpiece assembly 10 along guide means 85 and 86, which in the schematic view of FIGS. 1–3 are illustrated in the form of rod-like members. The workpiece advancement occurs parallel to the longitudinal axis of the workpiece assembly 10 which is also parallel to the longitudinal axis of the cutting tool assembly 12.

During the initial advancement the cutting head 47 and cutting tool 49 are received through the front frame member 20 with the path of the cutting tip 49 clearing the same. The cutting tip 49 carried on the cutting head 47 ultimately engages the marginal material defining the circular aperture 30 in the stator 28 as the workpiece continues its advancement. Removal of the marginal material by the cutting bit 49 transforms the circular aperture 45 into an oval or elliptical shape, the cutting head 47 and cutting tool 49 ultimately being introduced into the rear frame member 18 with a satisfactory clearance completely about the elliptical path traveled by the cutting tool. In this manner, by a single step boring operation, the stator 28 is provided with an elliptical-shaped cavity identified by the reference numeral 52 in the drawings.

The elliptical-shaped cavity 52 is formed by reason of engagement between the workpiece and cutter means as the latter is rotating about an axis which is disposed at an angle relative to the axis of travel of the workpiece. The angular relation is maintained throughout the engagement of the workpiece with the cutting tip as they move relative to one another.

The radius of the circular path of a cutting bit 49 is represented by the letter R in FIG. 1. This radius is measured from an axis which defines an acute angle with the longitudinal axis of the workpiece which is coincidental or parallel with the direction of the workpiece feed. The angle between these axes is represented by the letter A, and is illustrated in FIG. 1 as an acute angle of about 20°. Angles of this order have been used with a high degree of success, and in the main, any angle falling between 10° and 35° will be satisfactory with the ultimate choice being dictated by good pump design principles. The elliptical cavity substantially improves performance as pointed out in brief above, and in more detail in my copending application. The axis about which the cutting head 47 rotates generally coincides with the central axis of the circular cavity 25 formed in the workpiece 28 at casting.

FIG. 5 illustrates the pump stator 28 as it appears in cross section immediately prior to entry of the boring tool assembly 11. In this view the tool bit 49 is illustrated as being arranged for coincidental engagement with the opposite marginal areas of the aperture with the broken line extension 52 illustrating the shape of the oval cavity after enlargement of the aperture 25. The minor axis of the elliptical cavity is equal to $2R \cos A$ as indicated, while the major axis is simply the diameter of the circular path of travel of the cutting bit 49 and equal to the product 2R. From this it can be appreciated that the dimensions of the elliptical cavity may be varied by varying the angle of the tool assembly 35 relative to the axis of feed, which in the present case has been represented by the angle A.

The cavity formed may be technically defined as an elliptical cylinder, being shaped by the removal of all material in the path of the generatrix (tool bit 49) as it intersects with the plane of the workpiece moving in a straight line motion through the plane of the generatrix. As each of the points along the path of the tool bit 49 are projected along straight lines parallel to the axis of workpiece feed, the resultant shape is an elliptical cylindrical cavity, assuming of course that the material is removed within the confines of this projection. The positioning of the workpiece relative to the cutting tool assembly and vice versa in a non-parallel relation serves to readily permit variance of the minor dimensions of the elliptical cylinder.

Since the length of the minor axis of the elliptical cavity 52 is a function of the cosine of the angle, it will always be of lesser dimension than the diameter of the circular path traveled by the cutting tool 49. The differential dimension between the minor diameter of the ellipse and the diameter of the circular aperture 25 formed at casting will be maintained as close as possible to minimize the amount of material which must be removed from the stator during the boring operation.

When the workpiece cavity forming is complete, the workpiece holder assembly is retracted to the position shown in solid lines in FIGS. 1 and 2. With the workpiece 28 remaining firmly held in the rear and front frame members 18 and 20 respectively, the entire holder assembly 10 is shifted laterally along the path determined by the dove tail guide 16, to a position where the horizontally disposed minor axis of the elliptical cavity is in axial alignment with the longitudinal axis of the cutting tool assembly 12, and the vertically disposed major axis is slightly past the same. This position is shown at 87 being in phantom in FIG. 1 and in solid lines in FIG. 3. A suitable stop arrangement may be provided to limit the lateral travel of the work holder along the dove tail guide 16 to insure that the work holder stops slightly past the intersection of the major and minor axes of the ellipse. At this time the longitudinal or rotational axis of the cutting tool assembly 12 lies in a horizontal plane passing through the minor axis.

After the workpiece holder is stopped, the entire assembly is shifted longitudinally of the axis of the cutting tool toward the cutting head 82, at which time the cutting tool bit 84 engages the workpiece 28 in the manner seen in the enlarged view of FIG. 7 to form an arcuate seat which in the preferred form, is bisected by the minor axis of the elliptical cavity. The seat, identified by the reference 88, merges with the remaining portion of the ellipse so that the transition is practically undetectable. The seat 88 comprises a section of a right circular cylinder having a radius S as seen in FIG. 7, extending from a center axis represented by a point or dot disposed slightly above the intersection of the major and minor axes and indicated by the letter C with the respective axes being represented by the letters J, J′ and K and K′.

The workpiece assembly 10 is fed laterally to a position shown in phantom lines at 87′ in FIGS. 1 and 3, permitting the formation of an arcuate seat 88 in the workpiece 28, with exceptional accuracy. Substantial benefits are drived from the present arrangement in that the seat will always be generated about an axis which is parallel to the axis of the workholder assembly feed 10, and thus at right angles to the end surfaces of the stator. Thus the rotational axis of the stator will be perfectly disposed for rotor sealing with the seat when the pump is assembled.

A pump assembly 49 is illustrated in FIG. 8 having a stator 28 formed by the machine and method described above. The stator 28 illustrated forms one of the stages of the pump and is provided with seal plates or end plates by fasteners 55 extending through the apertures 32. The rectangularly shaped top portion 29 of the stator 28 is provided with an inlet 56 and outlet 57 formed by means of drilling or the like. As is evident on inspection of

FIG. 8, the inlet and outlet portions communicate with the enlarged ends of the stator cavity generally along the major diameter of the ellipse. The seat **88** is located between the inlet and outlet cavities and forms a fluidtight seal between the inlet and outlet portions when a circular rotor **59** keyed to an operating shaft is received for rotation in the cavity. A pair of oppositely directed vanes **61** and **61'** are identical in construction being received in longitudinal slots formed on opposite sides of the rotor **59** for radially spring biased running seal engagement with the elliptical walls of the cavity in the manner fully disclosed in my copending application. Suitable enlargements **91** and **92** may be provided at the inlet **56** and outlet port **57** to increase and improve pump conductance.

The enlarged areas of the cavity **52** at opposite ends of the major axis are disposed immediately below the inlet and outlet ports **56** and **57** respectively, with the rotor **59** positioned eccentric relative to the intersection of the major and minor axes of the cavity. Accordingly, the vanes **61** and **61'** extend and retract as they follow the curvature of the wall while the main body of the rotor **59** is in running sealing engagement with the seat **88** to provide fluidtight sealing between the inlet and outlet portions. Proper orientation of the stator relative to the enlarged areas of the cavity is made possible by the unique means and method to perform the machining of the rotor cavity and seat. Accurate formation of the seat for good sealing is always assured by the present machine and method since the work holder maintains the workpiece properly held between the steps of the cutting operation. The resultant reflection in the number of workpiece rejects **28** after cavity and seat formation is materially reduced since the machine and method described above accomplishes the same with unequaled accuracy considering the operation to be economically feasible for mass type production.

Obviously, certain modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and inventive concepts embodied herein and therefore only such limitation should be imposed as are indicated and fall within the spirit and scope of the appended claims.

I claim:

1. The method of final shaping of the cavity of a high vacuum pump stator, which stator is initially formed with a cylindrical bore which in turn is to be enlarged to define an elliptical cavity and thereafter provided with an arcuate seat interrupting but closely merging with the surface of the elliptical cavity and having a single radius with its center coinciding with the center of rotation of a vane-carrying pump rotor to be received in said cavity upon subsequent assembly of said pump, said method comprising introducing a first boring means into said cylindrical bore of said stator along a first axis coinciding with the geometric center of said cylindrical bore, rotating said first boring means during said introduction about a second axis which is in acute angular relation to said first axis and reshaping said cylindrical bore into an ellipse having a geometric center which is common with that of said cylindrical bore, separating said first boring means and said stator along said first axis, introducing a second boring means into said elliptical bore of said stator along a third axis which is perpendicular to the plane defined by the major and minor axes of said elliptical bore and which intersects said minor axis in radially offset relation to the intersection of said major and minor axes and which further coincides with the center of rotation of a rotor to be received in said cavity, rotating said second boring means during said introduction about said third axis and forming an arcuate seat in the surface of said elliptical bore, which arcuate seat closely merges with the adjacent elliptical surface portions of said bore, and thereafter separating said second boring means and said stator along said third axis.

2. The method of claim **1** wherein said first and second boring means are fixed relative to one another along said second and third axes respectively, and said stator is moved solely along said first and third axes as well as along a fourth axis intersecting said first and third axes and perpendicular thereto into alternative alignment with said first and third axes.

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FRANCIS S. HUSAR, *Primary Examiner.*