May 14, 1963 W. E. ROSE 3,089,638
IMPELLERS FOR FLUID HANDLING APPARATUS OF THE
ROTARY POSITIVE DISPLACEMENT TYPE
Filed Dec. 1, 1958 3 Sheets-Sheet 1

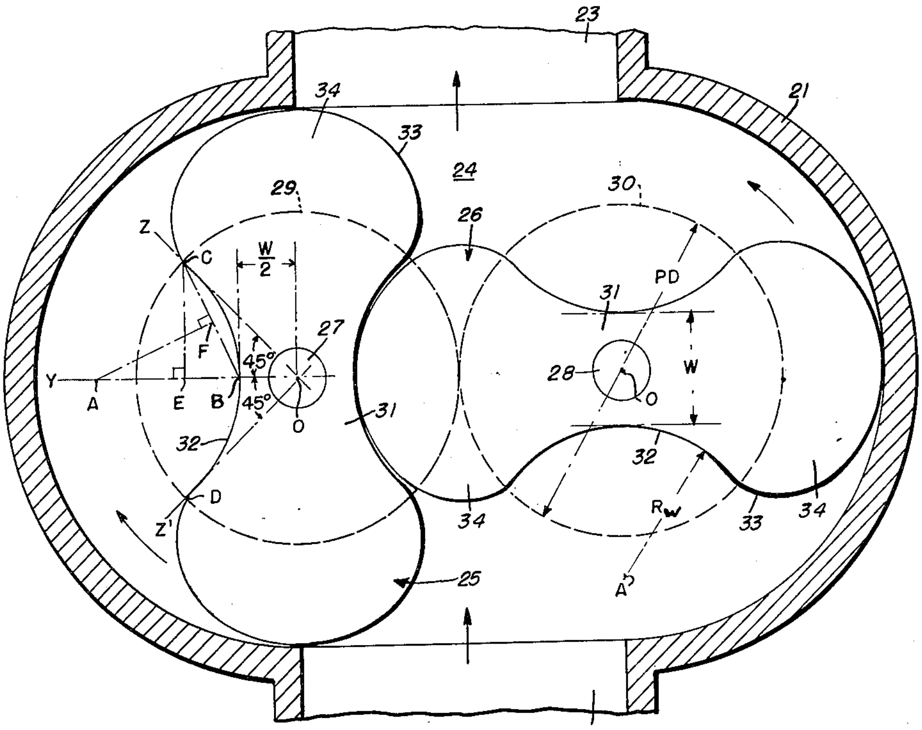

FIG. 1

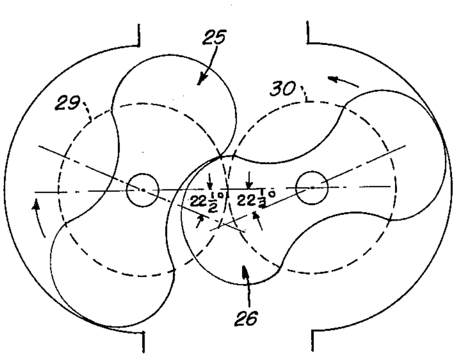

FIG. 2

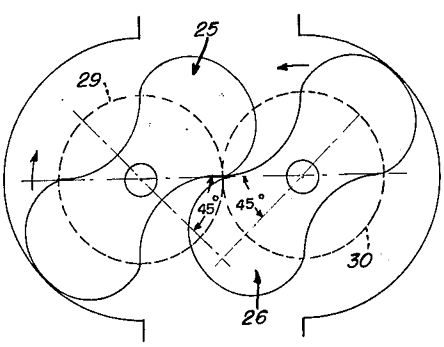

FIG. 3

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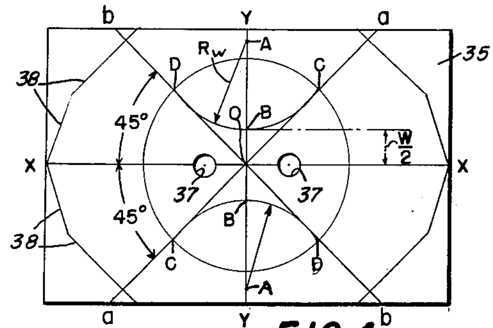

FIG.4

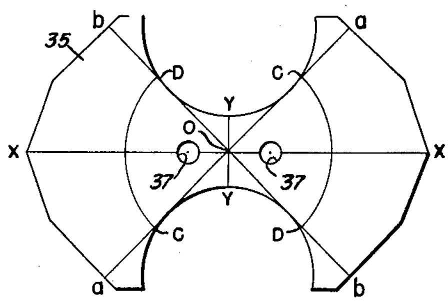

FIG.5

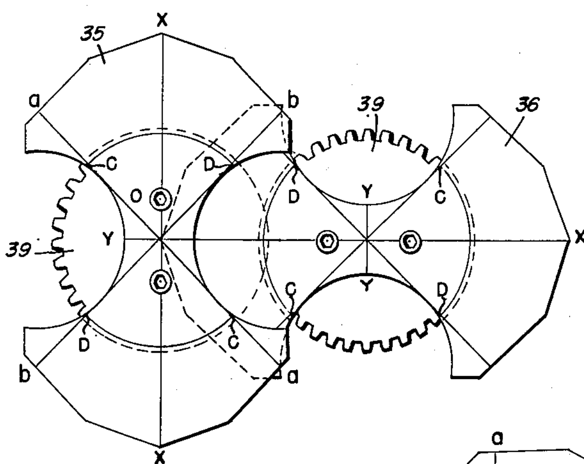

FIG.6

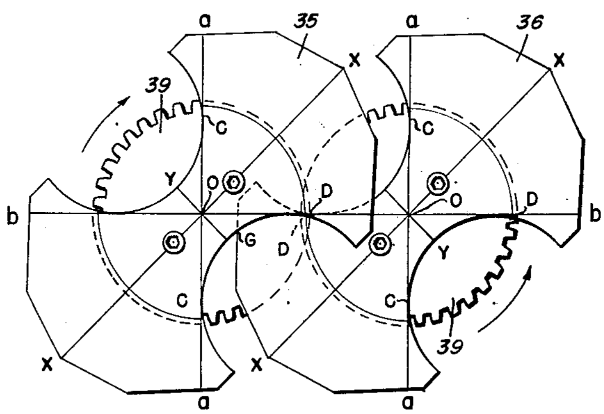

FIG. 7

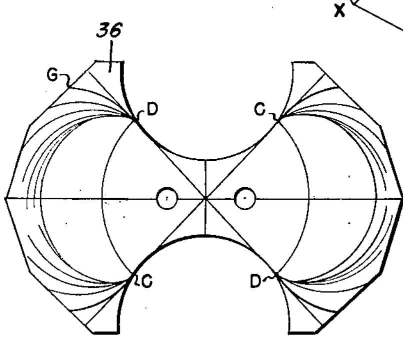

FIG.8

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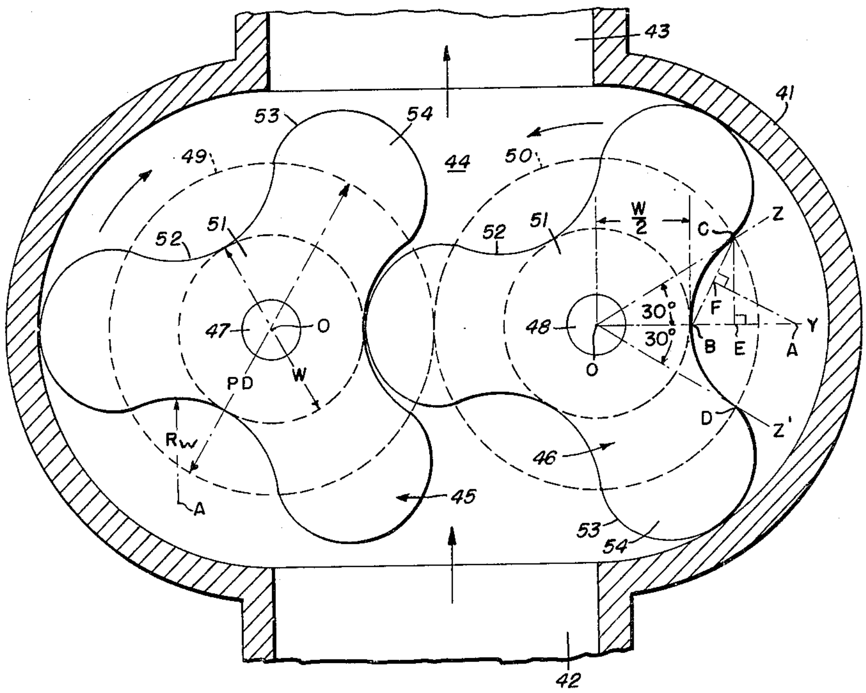

FIG. 9

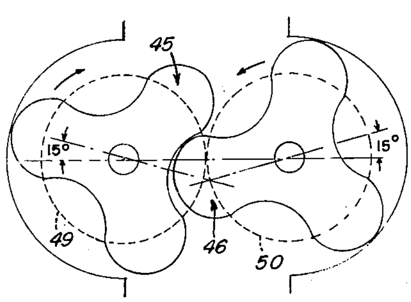

FIG. 10

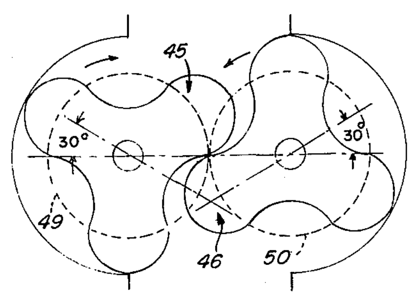

FIG. 11

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IMPELLERS FOR FLUID HANDLING APPARATUS OF THE ROTARY POSITIVE DISPLACEMENT TYPE

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Filed Dec. 1, 1958, Ser. No. 777,350
8 Claims. (Cl. 230—141)

This invention relates to fluid handling apparatus of the rotary positive displacement type, and is particularly directed to the provision of improved forms of lobed impellers for use in such devices.

Inasmuch as the invention is especially well adapted for embodiment in impellers for blowers of the well-known Roots type, the following disclosure will be directed primarily to this specific application of the inventive concept. By so doing, however, it is not intended to limit the scope of the invention to blowers because it will be obvious that it has equal utility in rotary positive exhausters, boosters, pumps and compressors.

The intermeshing impellers used in Roots type blowers have a characteristic shape comprising a central hub or waist portion which is fixed to a rotatable shaft and two or more lobe portions of identical contour or profile which extend radially outwardly from the waist. The convex profiles of the impeller lobes heretofore used have varied in form from circular arcs to curves of involute or cycloidal design, while the profiles of the waist sections between lobes have been concavely curved in different ways so as to receive and form substantially fluidtight seals with the lobes of mating impellers as the impellers rotate.

The impeller shapes of the prior art are difficult to construct and are subject to various disadvantages depending upon their specific profiles. For example, when a pair of mating impellers of the commonly used involute type rotate in cooperate relationship, they form trapped pockets which render such impellers unsuitable for handling fluids having entrained incompressible liquids such as sealing water, and which also impede performance when the blower is used as a vacuum booster due to the carry-over volumes which must be re-expanded. Cycloidal type impellers, on the other hand, make only single point contact as they rotate without the formation of trapped pockets, but their performance is limited from the standpoint of displacement.

The principal object of the present invention is to provide an improved form of lobed impeller for use in Roots type blowers and similar apparatus which is so contoured as to have practically only point contact with its mating impeller at all positions of relative rotation, thereby avoiding the formation of trapped pockets similarly to a cycloidal impeller, and to still maintain a relatively large displacement comparable to that of an involute impeller.

Another object is the provision of impellers of the character described having profiles of novel configuration which improve the noise characteristics and decrease the power requirements of rotary positive displacement devices in which they are incorporated.

A further object is to provide a relatively simple method of establishing the profiles and producing templates of impellers having the characteristics sought by the present invention.

These and other objects of the invention will appear more fully upon consideration of the detailed description of the embodiments of the invention which follows. In this connection, although only two specific forms of impellers and one method of establishing impeller profiles are described and illustrated in the accompanying drawings, it is to be expressly understood that these drawings are for purposes of illustration only and are not to be construed as defining the limits of the invention, for which latter purpose reference should be had to the appended claims.

In the drawings, wherein like reference characters indicate like parts throughout the several views:

FIG. 1 is a diagrammatic sectional view of a Roots type blower embodying a pair of two-lobe impellers having profiles of the novel form provided by the present invention, this view showing the impellers in what will be termed the 90° position, i.e., with the tip or central point of the lobe of one impeller contacting the central point of the waist of the other impeller, and indicating the geometry of the method of establishing the curvature of the waist portions of the impellers;

FIGS. 2 and 3 are diagrams indicating the relative positions of the two impellers of FIG. 1 and their single contact points when the impellers have turned through angles of 22½° and 45°, respectively, from the 90° position;

FIGS. 4, 5, 6, 7 and 8 are diagrammatic plan views illustrating one method of generating the convex curves of the lobe portions of the impeller profiles and of constructing templates for the manufacture of impellers embodying the present invention; and

FIGS. 9, 10 and 11 are diagrammatic views similar to FIGS. 1, 2 and 3, respectively, of a blower comprising a pair of three-lobe impellers embodying the invention.

In general, an impeller constructed in accordance with the present invention may be described as having a waist portion defined by concave circular arcs the ends of which are substantially coincident with the pitch circle of the timing gear fixed to the impeller shaft, while the convex profiles of the lobe portions are continuous non-circular conjugate curves generated from the waist profiles of the mating impeller. The arc defining each segment of the impeller waist portion subtends an angle at the axis of the impeller shaft equal to $360°/2n$, where n is the number of lobes, i.e., 90° in the case of a two-lobe impeller and 60° in a three-lobe impeller. In order to attain the improved results sought by the present invention, the width or thickness of the impeller waist should be maintained within the range of from about ⅓ to about ½ the gear pitch diameter for two-lobe impellers, and from about ½ to about ⅔ the gear pitch diameter for three-lobe impellers.

As will be explained hereinafter, the radius of the circular arc defining the surface of each waist segment of impellers constructed in accordance with the present invention may be determined by the formula

$$R_w=\frac{\left[\cos\left(\frac{360°}{4n}\right)\times\frac{PD}{2}-\frac{W}{2}\right]^2+\left[\sin\left(\frac{360°}{4n}\right)\times\frac{PD}{2}\right]^2}{\cos\left(\frac{360°}{4n}\right)\times PD-W} \quad (1)$$

wherein R_w is the impeller waist radius, n is the number of impeller lobes, PD is the gear pitch diameter and W is the waist width or thickness. The dimensions R_w, PD and W for two- and three-lobe impellers are indicated in FIGS. 1 and 8, respectively. The curve defining the convex surface of each lobe, however, is not readily susceptible of definition by formula, but may be generated in a relatively simple manner as later described with reference to FIGS. 4–8.

Referring now to FIG. 1, the device diagrammatically illustrated therein is a Roots type blower comprising a casing or cylinder **21** having two semicylindrical wall portions laterally separated to provide a fluid inlet **22** at the bottom, an outlet **23** at the top and a pumping chamber **24** in the central portion of the casing, and a pair of intermeshing impellers 25 and 26 of identical shape which are mounted on parallel shafts 27 and 28 and are adapted to be rotated thereby in opposite directions at a constant velocity ratio through a pair of timing gears, the pitch circles of which are indicated in broken lines at 29 and 30. The shafts 27 and 28 are coaxial with the semicylindrical wall portions of casing 21 and are so spaced laterally that, when the impellers are in the 90° position indicated in FIG. 1, the central point of the profile of one lobe of one impeller is in single point contact with the central point of the profile of one side of the waist of the other impeller.

It will be understood, of course, that each of the impellers is elongated in a direction perpendicular to the plane of FIG. 1 and has a uniform cross-sectional shape of the form shown in the figure. In the interest of simplicity, the description herein will refer to the lines which define the sectional contour or profile of the impellers, rather than to the surfaces of which said lines are the axial projections.

It will also be understood that, in referring to "contact" between the mating impellers, it is not intended to imply that the impellers must actually touch one another, because at the "point of contact" between impellers constructed in accordance with the present invention there is usually an accurately gauged clearance on the order of .017". The term "contact" as used herein should therefore be construed to include the situation wherein there is a small working clearance between the closest points of the impellers at all positions of relative rotation.

The central or waist portion 31 of each impeller surrounding the associated shaft is bounded by a pair of circular arcs 32 of identical radius, the ends of which arcs are substantially coincident with pitch circles 29 and 30 and are connected by convex curves 33 which define the outer ends or lobe portions 34 of the impeller. Curves 33 are so formed that, as the impellers rotate in opposite directions as indicated by the arrows in FIG. 1, at each instant the active lobe of one impeller contacts the waist of the other at only one point. For example, when the impellers have rotated 22½° from the 90° position of FIG. 1 to that illustrated in FIG. 2, the contact between the lobe of impeller 26 and the waist of impeller 25 is still at a single point, but the point has moved clockwise on the lobe and counterclockwise on the waist from the central point shown in FIG. 1. Rotation through another 22½° to the 45° position of FIG. 3 shifts the contact further along the impeller profiles, clockwise in the case of impeller 26 and counterclockwise on impeller 25, to the points where the waist arc of impeller 25 joins the lobe curve thereof and where the lobe curve of impeller 26 joins the waist arc thereof.

The radius to be used for the waist arcs 32 of impellers constructed in accordance with the present invention may be determined geometrically in the manner indicated in FIG. 1. As shown, the first step is to draw a line OY outwardly from the center O of pitch circle 29 in a horizontal direction, i.e., collinear with the centers of both pitch circles, and then located a point B on line OY at a distance from center O equal to ½ the selected waist width, i.e., $W/2$. As previously indicated, the width of the waist (W) of a two-lobe impeller should be not less than about ⅓ the gear pitch diameter (PD), in order to insure adequate mechanical strength of the impeller and shaft, and not more than about ½ the gear pitch diameter, in order to provide adequate displacement. Preferably, the waist width of a two-lobe impeller is made equal to about ⅜ the gear pitch diameter.

The next step is to draw two additional radial lines OZ and OZ′ making angles of 45° with line OY and intersecting pitch circle 29 at points C and D, respectively. The center of a circular arc passing through the points C, B and D may then be determined in well known manner by drawing the line CB and erecting a perpendicular at the midpoint F thereof, the point A where said perpendicular intersects line OY being the center. The circular arc defining the waist profile may then be struck using

point A as a center and the distance AB as the radius, terminating the arc at the points C and D on pitch circle 29.

The length of waist radius AB, i.e., R_w, may also be determined mathematically from the formula hereinbefore set forth, which formula is derived as follows from the relationships between the elements of the geometrical construction illustrated in FIG. 1, including all of the lines previously mentioned plus a perpendicular CE dropped from point C to line OA.

From the right triangles ABF and BCE it is evident that

$$\frac{AB}{BF}=\frac{BC}{BE}$$

or

$$AB=\frac{BC\times BF}{BE} \tag{2}$$

By reference to FIG. 1, it will also be seen that

$$BC=\sqrt{BE^2+CE^2}$$

$$BF=\frac{BC}{2}$$

$$BE=EO-BO=\cos 45°\times CO-BO$$

and

$$CE=\sin 45°\times CO$$

Substituting these values for BC, BF and BE in Equation 2 gives

$$AB=\frac{(\cos 45°\times CO-BO)^2+(\sin 45°\times CO)^2}{2(\cos 45°\times CO-BO)} \tag{3}$$

In Equation 3, the terms CO and BO are the radius of the gear pitch circle and ½ the waist width, respectively, and are therefore known values, $PD/2$ and $W/2$, respectively. The angle 45° may also be expressed as $360°/4n$, where n is the number of lobes of the impeller, because, as previously stated, the arc 32 defining each side of the waist of any two-lobe impeller embodying the present invention subtends an angle of 90° at the axis of the impeller shaft, i.e., the point O. Substituting these known values in Equation 3, the formula for waist radius AB, i.e., R_w, becomes

$$R_w=\frac{\left[\cos\left(\frac{360°}{4n}\right)\times\frac{PD}{2}-\frac{W}{2}\right]^2+\left[\sin\left(\frac{360°}{4n}\right)\times\frac{PD}{2}\right]^2}{\cos\left(\frac{360°}{4n}\right)\times PD-W} \tag{1}$$

The convex curves 33 defining the lobe profiles of impellers embodying the invention may be generated from the waist arcs 32 by the method illustrated in FIGS. 4–8, which are also illustrative of a method of making templates to be used in machining the impellers.

The first step is to obtain two rectangular metal plates 35 and 36 of suitable size and thickness, only one of which is shown in FIG. 4, and to describe on each plate the perpendicular axes X—X and Y—Y, and two 45° lines *a—a* and *b—b*, all passing through the point O which represents the impeller axis. On each plate is also described, from point O as a center, a circle having a diameter equal to PD, the diameter of the gear pitch circle of the timing gears with which the impellers are to be used. The points B are then marked on axis Y—Y at distances from point O equal to $W/2$, i.e., ½ the desired waist width. Points A are next marked on the Y—Y axis at distances from points B equal to the waist radius R_w, as determined in accordance with formula 1. From points A as centers the waist arcs CBD are then described.

In order to facilitate the operations hereinafter described, each plate is provided with a pair of drilled holes 37 located on axis X—X on opposite sides of point O which serve to receive bolts or screws for securing the plates to machining fixtures and rotating gears. Each plate is also marked with lines **38** to indicate the corner portions of the plate which should be removed for clearance purposes during the lobe curve generating procedure.

After machining off the corners of each plate down to the lines **38**, the metal between waist arcs CBD and the upper and lower edges of the plate is removed, and the waist profiles defined by arcs CBD are accurately ground. At the completion of these operations, each of plates **35** and **36** will be in the form shown in FIG. 5, it being understood that all of the above-described operations are performed on each plate.

Plates **35** and **36** are next mounted on a rotating gear fixture **39** with plate **35** on top of and just touching plate **36**, and with the Y—Y axis of plate **35** aligned with the X—X axis of plate **36**, as indicated in FIG. 6. Gauge blocks may be used for support and proper spacing of the plates, and bolts or screws may be inserted in holes **37** in order to hold the plates in proper position on the gear fixture. It will be understood that the gears of fixture **39**, portions of which are visible through the machined-out waist portions of the plates, have the same pitch diameter as the impeller timing gears. In order to insure that plates **35** and **36** are properly mounted relatively to one another when fixed to the gear fixtures, the plates should be rotated through 45° to the position shown in FIG. 7 and checked to see that the 45° lines *b—b* of both plates fall into alignment. In this position, one end of one of the waist profile arcs of plate **35** is directly above the point on the pitch circle of plate **36** which defines one end of one of the waist profile arcs of the latter.

The lobe curves of plate **36** may be generated by tracing a great series of fine marked lines from the waist profiles of top plate **35** onto bottom plate **36**, turning the gears of fixture **39** to a different position for each tracing. For example, with the plates in the 45° position of FIG. 7, the portion of the arc defining the right-hand side of the waist of plate **35** which overlies the portion of plate **36** outside the pitch circle thereof, i.e., from point D to point G, is traced onto the surface of plate **36**. The gears are then turned through a small angle so as to rotate plates **35** and **36** in counterclockwise and clockwise directions, respectively, and the tracing operation is repeated, again following the waist curve of plate **35** from point D in a counterclockwise direction. By continuing this tracing operation while the gears are rotated in small increments through a total angle of 90°, i.e. until point C of the right-hand waist curve of plate **35** becomes coincident with point C of the lower curve of those portions of the traced lines lying closest to the pitch circle will produce a clearly visible profile for the lobe of plate **36**, as indicated in FIG. 8.

After turning the gears through another 90° in the same direction, the tracing operation may be repeated beginning with coincidence of the point D of the waist curve at the left-hand side of plate **35** (as viewed in FIG. 7) and the corresponding point D of the upper waist curve of plate **36**. When the two series of lines have thus been traced, the face of plate **36** will have an appearance similar to that illustrated roughly in FIG. 8, from which it can be seen that the generated lobe profiles are readily discernible. It will be understood, of course, that FIG. 8 does not shown as many tracings as would be made in practice.

Plates **35** and **36** are then removed from gear fixture **39** and reassembled with plate **35** in the position previously occupied by plate **36**, and vice versa, whereupon the tracing procedure above described is repeated, using the waist curves of plate **36** to generate the lobe profiles of plate **35**.

After both plates have been so marked, those portions of the profile tracings lying closest to the pitch circles may be punch marked and the generated lobe curves may be faired through the punch marks. The plates are then machined and ground down to the generated lines to provide finished templates having the contours illustrated in FIG. 1, usable in known manner for machining of the impeller castings.

Referring now to FIGS. 9–11, the blower shown therein represents another embodiment of the present invention as applied to three-lobe impellers. As illustrated, blower casing **41**, having a fluid inlet **42**, outlet **43** and pumping chamber **44**, houses a pair of impellers **45** and **46** which are mounted on and rotatable by shafts **47** and **48**, respectively, and are synchronized by timing gears indicated by the pitch circles **49** and **50**.

Each of impellers **45** and **46** has a waist portion **51** defined by three circular arcs **52** of identical radius, the ends of which arcs are substantially coincident with pitch circles **49** and **50** and are connected by convex curves **53** which form the profiles of the lobe portions **54** of the impeller. Curves **53** are so formed that, as the impellers rotate in opposite directions as indicated by the arrows in FIG. 9, one lobe of one impeller contacts one of the waist segments of the other at only a single point. For example, when the impellers have rotated 15° from the position shown in FIG. 9 to that illustrated in FIG. 10, the contact between the lobe of impeller **46** and the waist of impeller **45** remains at a single point, although the point has moved clockwise on the lobe and counterclockwise on the waist from the central point shown in FIG. 9. Rotation through another 15° to the 30° position of FIG. 11 results in shifting of the point of contact further along the impeller profiles, in the same directions as those just mentioned, to the points where the waist arc of impeller **45** joins the lobe thereof and where the lobe curve of impeller **46** joins the waist arc thereof.

The radius of each of waist arcs **52** may be determined geometrically in the same manner as that previously described with reference to the two-lobe embodiment of FIG. 1, except that each of radial lines OZ and OZ′ from the center O of pitch circle **50** makes an angle of 30°, instead of 45°, with horizontal line OY. The length of the waist radius for the three-lobe impellers of FIG. 9 may be determined mathematically by the same Formula 1 as that previously discussed in connection with the two-lobe embodiment of the invention.

Likewise, the convex curves **53** which define the contours of lobes **54** may be generated from the waist arcs **52** by a procedure similar to that previously described and illustrated in FIGS. 4–8.

There is thus provided by the present invention an improved form of lobed impeller for use in fluid handling apparatus of the rotary positive displacement type which combines the advantages, with a minimization of the disadvantages, of the various types of impellers heretofore used. Impellers constructed in accordance with this invention provide a continuous, substantially single contact point of action which eliminates trapped pockets, and at the same time provide greater displacement than those impellers of the prior art which are characterized by point contact of the mating impellers. In comparison with the commonly used involute form, the impellers of the present invention not only are capable of handling incompressible fluids, but also deliver more cubic feet of fluid per horsepower per minute and are quieter in operation. The invention also provides a relatively simple method of developing the profiles of impellers having the desired characteristics, and of producing said profiles in the form of templates.

Although two specifically different forms of impellers embodying the invention and one procedure for developing their profiles have been described and illustrated herein, it will be obvious that the invention is not limited to these illustrative examples, but is capable of a variety of mechanical and procedural embodiments. Reference is therefore to be had to the appended claims for a definition of the limits of the invention.

What is claimed is:

1. Fluid handling apparatus of the rotary positive displacement type comprising a pair of lobed impellers

mounted on parallel shafts and rotatable at a constant velocity ratio through timing gears fixed to said shafts, each of said impellers having a central waist portion adapted to be mounted on one of said shafts and a plurality of identically shaped lobe portions extending radially outwardly from said waist portion, the profile of each of said impellers consisting of a like plurality of identical concave circular arcs of uniform radius defining said waist portion and a like plurality of identical convex non-circular curves defining said lobe portions, each of said circular arcs subtending an angle at the axis of the impeller shaft equal to 360°/2*n*, where *n* is the number of said lobe portions, and each of said non-circular curves being generated from a circular arc identical with those defining said waist portion so that, when said impellers are rotated in opposite directions at the same velocity through said timing gears, there is substantially point contact only between said impellers at all positions of relative rotation.

2. Fluid handling apparatus as defined in claim 1 wherein the thickness of the waist portion of each of said impellers is between about ⅓ and about ⅔ the pitch diameter of the associated timing gear, and the ends of each of the circular arcs defining said waist portion are substantially coincident with the pitch circle of said timing gear.

3. In a fluid handling device of the rotary positive displacement type, a pair of lobed impellers mounted on parallel shafts and rotatable at a constant velocity ratio through timing gears fixed to said shafts, each of said impellers having a central waist portion and two identically shaped lobe portions extending in diametrically opposite directions from said waist portion, the profile of each of said impellers consisting of two concave circular arcs of uniform radius defining said waist portion and two convex non-circular curves defining said lobe portions, the thickness of said waist portion being between about ⅓ and about ½ the pitch diameter of said timing gears, each of said circular arcs subtending an angle at the axis of the associated shaft equal to 90°, and each of said non-circular curves defining the lobe portions of each impeller being generated from a circular arc identical with those defining said waist portion so that, when said pair of impellers are rotated in meshing relationship through said timing gears, there is substantially point contact only between said impellers at all positions of relative rotation.

4. In a fluid handling device of the rotary positive displacement type, a pair of lobed impellers mounted on parallel shafts and rotatable at a constant velocity ratio through timing gears fixed to said shafts, each of said impellers having a central waist portion and three identically shaped lobe portions extending radially outwardly from said waist portion, the profile of each of said impellers consisting of three concave circular arcs of uniform radius defining said waist portion and three convex non-circular curves defining said lobe portions, the thickness of said waist portion being between about ½ and about ⅔ the pitch diameter of said timing gears, each of said circular arcs subtending an angle at the axis of the associated shaft equal to 60°, and each of said non-circular curves defining the lobe portions of each impeller being generated from a circular arc identical with those defining said waist portion so that, when said pair of impellers are rotated in meshing relationship through said timing gears, there is substantially point contact only between said impellers at all positions of relative rotation.

5. For use in fluid handling apparatus of the rotary positive displacement type having a pair of lobed impellers mounted on parallel shafts and rotatable at a constant velocity ratio through timing gears fixed to said shafts, an impeller having a central waist portion coaxial with the associated shaft and timing gear and a plurality of identically shaped lobe portions not exceeding three in number extending radially outwardly from said waist portion, the profile of said impeller consisting of a like plurality of concave circular arcs of uniform radius defining said waist portion and a like plurality of convex non-circular curves defining said lobe portions, each of said circular arcs subtending an angle at the axis of said associated shaft equal to 360°/2*n* where *n* is the number of said lobe portions, each of said non-circular curves being generated from a circular arc identical with those defining said waist portion, the radius of each of said circular arcs being so related to the pitch diameter of the timing gears, the thickness of the waist portion and the number of said lobe portions that

$$R_w = \frac{\left[\cos\left(\frac{360°}{4n}\right)\times\frac{PD}{2}-\frac{W}{2}\right]^2\left[\sin\left(\frac{360°}{4n}\right)\times\frac{PD}{2}\right]^2}{\cos\left(\frac{360°}{4n}\right)\times PD-W}$$

where R_W is the arc radius, *n* is the number of said lobe portions, PD is the gear pitch diameter and W is the waist thickness and lies in the range of from about *PD*/3 to about 2*PD*/3.

6. An impeller as defined in claim 5 wherein *n* is equal to 2 and W is between about *PD*/3 and about *PD*/2.

7. An impeller as defined in claim 5 wherein *n* is equal to 2 and W is equal to about 3*PD*/8.

8. An impeller as defined in claim 5 wherein *n* is equal to 3 and W is between about *PD*/2 and about 2*PD*/3.

References Cited in the file of this patent

UNITED STATES PATENTS

166,295	Palmer et al.	Aug. 3, 1875
587,907	Ames et al.	Aug. 10, 1897
1,442,018	Wendell	Jan. 9, 1923
1,676,202	Isom et al.	July 3, 1928
1,769,153	Meyer	July 1, 1930
1,798,059	Bilgram et al.	Mar. 24, 1931
2,578,187	Hill et al.	Dec. 11, 1951

FOREIGN PATENTS

10,128	Great Britain	of 1884
282,752	Great Britain	May 31, 1928
566,077	Belgium	Apr. 15, 1958
861,733	Germany	Jan. 5, 1953
953,289	Germany	Nov. 29, 1956
1,170,967	France	Sept. 29, 1958