United States Patent [19]

Huse

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[54] **LIQUID RING VACUUM PUMP-COMPRESSOR**

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[52] **U.S. Cl.** **417/68**

[51] **Int. Cl.** **F04c 19/00**

[58] **Field of Search** 417/68, 69

[56] **References Cited**

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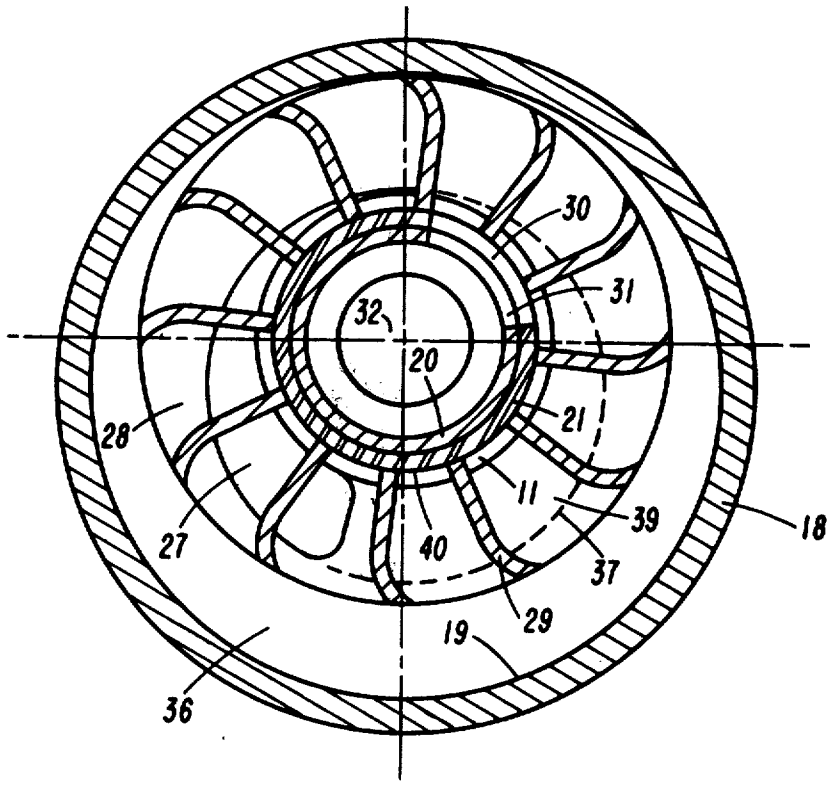
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Assistant Examiner—Richard E. Gluck

[57] **ABSTRACT**

A single stage axial flow liquid ring pump having separate rotor blade zones for suction and for discharge permitting use of contoured blade angles and sleeves to reduce fluidic shock, reduce noise and to improve performance by reduction of slippage and friction losses.

8 Claims, 6 Drawing Figures



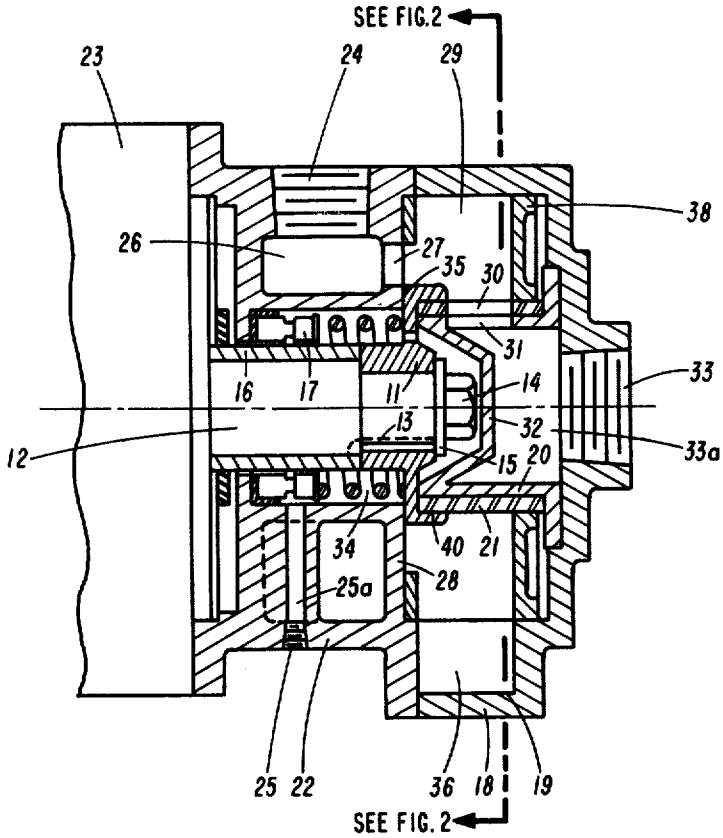


FIGURE 1

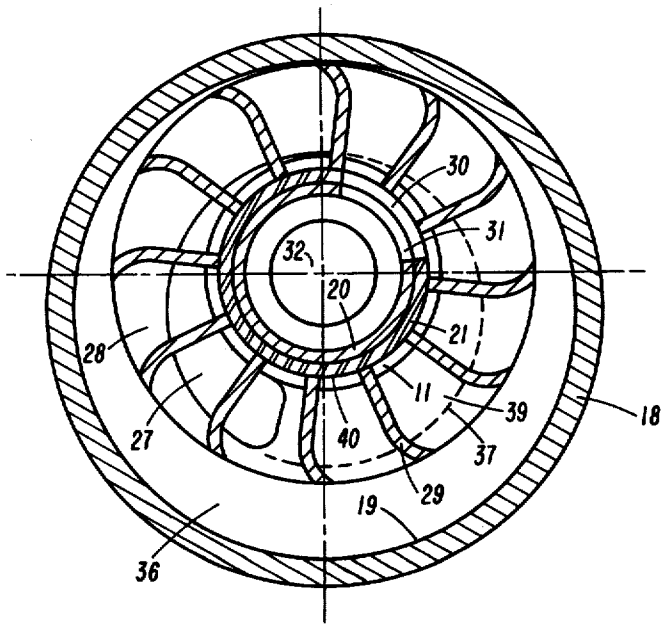


FIGURE 2

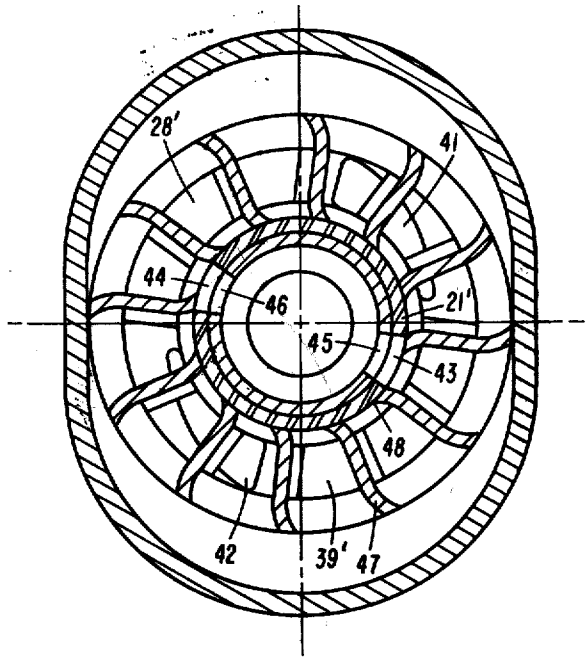


FIGURE 3

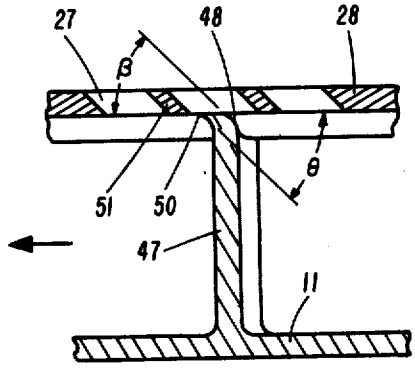


FIGURE 4

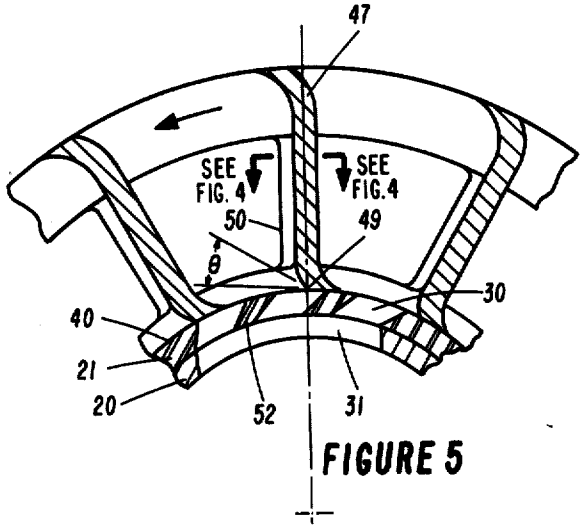


FIGURE 5

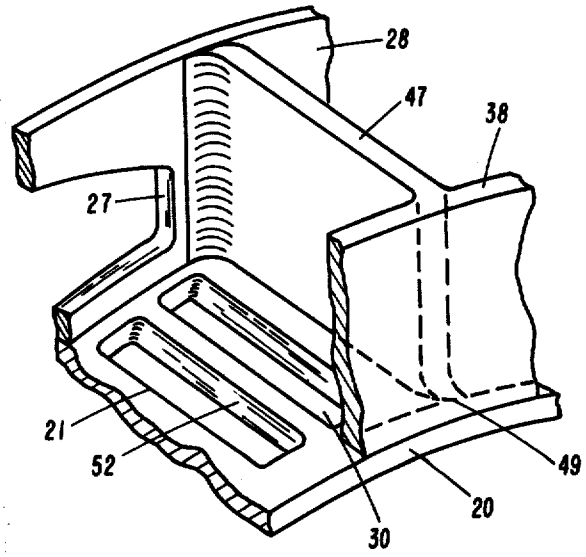


FIGURE 6

LIQUID RING VACUUM PUMP-COMPRESSOR

BACKGROUND OF THE INVENTION

This invention relates to liquid ring vacuum pumps and compressors.

The liquid ring principle is a well established art. Typically, a liquid ring pump consists of a multi-bladed rotor mounted on a shaft and arranged so as to rotate freely within an eccentric or elliptical casing. Water introduced in the casing is acted upon by the blades of the rotor, and centrifugal force causes the water to form a ring which follows the inner contour of the casing. As the ring surges outward and inward in alteration it creates a piston action in the buckets formed by the rotor blades, and this action is employed to suck in air or gas on the outward stroke and compress it on the inward stroke. Port openings, either centrally located or on the sides of the rotor, provide inlet and discharge means for the gas being pumped.

The efficiency of a liquid ring vacuum pump or compressor is determined by the relationship of actual energy required to pump a gas as related to the theoretical work energy required. The difference between actual and theoretical represents energy losses. In liquid ring pumps these losses consist mainly of (a) friction losses caused by liquid ring velocity in the pump casing, (b) losses of gas displacement caused by internal slippage of gas from the discharge pressure to the lower suction pressure, and (c) hydraulic losses caused by friction drop in passages and conduits through which the fluid flows. Of these sources of loss of efficiency those losses due to casing friction are determined by the properties of the liquid comprising the ring, the velocity of the liquid ring, and the surface finish of the casing, none of which are pertinent to this invention. This invention does address itself to the other two causes of efficiency losses; those of internal gas slippage, and hydraulic losses.

In the design of liquid ring pumps there are two common arrangements for directing the gas into and out of the pumping chamber. The inlet and discharge ports are arranged either on flat plates on the side of an open bladed rotor, or they are arranged internally in a centrally located port cylinder or cone around which a shrouded rotor rotates. In both instances the port member is stationary and the rotor is in rotation and in very close contact with the port opening.

In the circular or single lobe design there is one pumping cycle per revolution of the rotor, and hence one inlet and one discharge port. On elliptical or two-lobe designs there are two pumping cycles per revolution and hence two inlet and discharge ports. In the known art the inlet and discharge ports are located adjacently on the same surface. In the case of flat sided pumps the inlet and discharge ports are located on a common flat plate with the discharge port displaced from the inlet port in the direction of rotation. In designs employing a central port cylinder or cone the inlet and discharge ports are likewise located on the same surface, this surface being formed by the periphery of the cone or port cylinder. The discharge port is likewise displaced from the inlet port in the direction of rotation.

The arrangements as described above make it imperative that the clearances between the rotating rotor portion and the stationary ported portion be as tight as possible so as to minimize slippage losses between inlet

and discharge ports. In common practice the displacement of the inlet and discharge ports is approximately twenty degrees of arc or one-third radian. This arrangement dictates that the points of greatest and least pressure are displaced from each other by only a relatively small gap.

In order to minimize slippage losses it is necessary to set the clearances as close as possible and also provide for liquid injection between parts in rotation. The liquid used to seal the clearances makes its way to the liquid ring and then to discharge. Thus, on a pump with very tight clearances less sealing water is required than on pumps having loose clearances. As wear progresses in the pump its water requirements are increased to meet the increased sealing requirements. It is obvious that slippage losses are increased when the pressure differential between inlet and discharge is increased. Thus, it is observed that the capacity of a liquid ring vacuum pump falls off rapidly as higher vacuum is achieved. For this reason single stage vacuum pumps are normally good for operation up to 27 inches Hg vacuum, or a compression ratio of ten to one. The improved design described in the invention reduces slippage losses and permits operation up to twenty-nine inches Hg vacuum in single stage — a three fold improvement over existing single stage pump designs.

Existing pump designs require complex passages to direct the flow of gas and liquid into the pump and to discharge. On flat sided pumps the chamber comprising the inlet is compartmented so that the incoming gas is directed to one or more inlet ports, and the discharge fluids from one or more discharge parts must be separated from the inlet by similar compartments and passages. These passageways are located in the heads which are located outboard from the port plate. Centrally located port cylinders and cones also require compartmentation of the internal porting members and also the pump heads. These complicated passageways constrict the flow of fluids and cause friction losses. They furthermore complicate the casting, manufacture and assembly of parts.

Because of the complexity of existing designs the port openings are normally of intricate design and are formed in the casting process. Because of the necessity of separating suction and discharge passages, the use of sleeves on parts in close or sliding contact is not used. Parts subject to wear are either replaced, remachined, or metallized and remachined. This invention simplifies pump construction and permits the economical use of sleeves of any suitable material.

Liquid ring pumps of current designs utilize rotor blades which, in either flat sided or central ported arrangements, are in contact with the suction port and the discharge port at the same portion of the blade. For example, in a centrally ported design the rotor blades spin around a centrally located port cylinder. As the rotor blade passes over the suction port the receding liquid ring pulls air or gas radially outward into the chamber formed by the blades and rotor shrouds. As the blades pass over the discharge port the gas or air is displaced radially inwardly into the discharge port. To perform these dual functions the blade at the point of contact with the port must be approximately 90° from the direction of rotation. This necessary arrangement creates hydraulic or fluidic shock because the blade shears the gas and liquid stream. The result of this fluidic shock is friction loss and high noise level. In the im-

proved pump described in this invention the suction and discharge portions of the rotor blades are displaced from each other, permitting the use of angular contact of blade to fluid stream, thus reducing fluidic shock and substantially reducing the noise caused by the fluid stream shear.

SUMMARY OF THE INVENTION

The liquid ring pump described in this invention is equally adaptable for use as a vacuum pump or as a compressor.

It is a primary object of the invention to provide a means whereby the suction port is removed from close proximity to the discharge port so as to reduce slippage losses caused by fluids bypassing from the discharge port to the lower pressure suction ports. This feature greatly improves pump efficiency and permits operation with water seal in single stage out to twenty nine inches Hg vacuum, which is unobtainable with other single stage liquid ring vacuum pumps. This improvement is also significant when the pump is used as a compressor.

Disassociation of the inlet and discharge port is achieved by placing the suction port or ports on a flat plate located beside the rotor. The rotor blades are either open or shrouded at the point of contact with the port plate. The discharge port, or ports, are placed on a central port cylinder or cone. The rotor blades communicate with the discharge port by means of openings on the rotor inner bore, and air or gas and accompanying liquid is discharged radially into the central porting member, and thence axially to pump discharge. This separation of the functions of the suction and discharge porting reduces slippage losses to a minimum.

A further object of the invention is to provide for efficient pump operation in the full operating range with relatively loose clearances. Because the suction and discharge ports are not in close proximity, slippage losses are reduced. Thus, the pump may be expected to perform satisfactorily with worn parts whereas a conventional pump would suffer serious loss of capacity and ability to attain high vacuum.

A further object of the invention is to simplify the conduits and passage through which the fluids must travel from inlet to final discharge. By disassociating suction and discharge functions the inlet ports are simply connected to a common suction chamber. The discharge ports are likewise connected to a common chamber. The flow of fluids is unimpeded, and friction losses can be reduced to practically nil by generously sizing the passages so as to attain low fluid velocities. This benefit is of particular importance on double lobe or multiple lobe pump designs where congestion of passages is a serious handicap with existing pump designs.

It is an object of the invention to provide axial flow through the pump, thus simplifying pump components and also reducing friction losses.

An important object of the invention is to permit the use of a sleeve on the discharge port cylinder. While sleeves perhaps could be adapted to other pumps utilizing the central port cylinder design, such designs currently have both suction and discharge ports located in the port cylinder, and bonding the sleeve to the port cylinder so as not to have any leakage or communication between inlet and discharge ports would be a difficult and costly process. Application of sleeves to the pump design covered by this invention is easy and inexpensive.

A corollary benefit and object of this invention is the use of special seal materials such as fluorinated hydrocarbons of the Teflon family. Such seal materials are self lubricating and this lubricity permits operating the mating port cylinder and rotor with sliding contact, further reducing slippage losses. Other sleeve materials are also a part of the scope of this invention as benefits can be gained by the use of rubber and urethane materials for abrasion resistance, titanium and copper nickel alloys for chloride resistance, stainless steel, bronzes and ceramics for special applications. It is obvious that the cost of sleeve fitted parts, made possible by this invention, would be far less than the cost of fabricating the entire part from a special material. There are further benefits to be gained in relation to parts replacement and servicing the pumps.

An additional feature of the invention is the compartmentalizing of the mechanical seal in such way that the seal cooling fluid removes heat from the seal faces and then is introduced into the pump. The mechanical seal is thus always kept under positive pressure, even on vacuum service. When the vacuum pump or compressor is handling dirty gases or gases of a corrosive nature these impurities or corrosives cannot enter the mechanical seal area, thus ensuring satisfactory seal life even under extreme operating conditions. Frequently vacuum pumps on wet vacuum service, such as vacuum filtration, are subjected to slugs of liquids containing sand, grit or impurities, and these impurities could not affect the mechanical seal.

A primary feature of the invention is the unique means whereby the rotor blade area in contact with the suction port is not associated with the discharge port. Likewise, the rotor blade area in contact with the discharge port is not in contact with the suction port. By utilizing separate blade areas for different functions, it is possible to design the blade to provide optimum performance. To accomplish this the suction blade area is angled toward the direction of flow so that instead of shearing the fluid flow at 90° the blade can slice the fluid at an angle optimized for the blade and fluid relative velocities. The air foil in the trailing edge of the blade at the suction port creates a vacuum which assists in sucking air or gas into the buckets formed by the receding liquid ring.

Conversely, by having the leading edge of the blade at the discharge port angle back away from the direction of rotation the discharge of air and water is smoothed resulting in reduction in pulsation and higher discharge compression.

The use of contour blade areas as described in the invention at the inlet and discharge portions reduces substantially the noise caused by fluidic shock as well as improves over all pump efficiency, both as vacuum pump and compressor.

Another feature of the invention is the use of guide vanes in the suction and discharge ports so as to direct the fluid flow to obtain the optimum contact angle between the rotor blade and fluid stream. The addition of guide vanes results in improved efficiency and substantially reduced noise. The guide vanes offer an additional benefit when the pump is required to handle large quantities of liquid, or liquid slugs. The vanes absorb hydraulic shock by breaking up the liquid stream before it comes into contact with the rotor blades.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal sectional view of the liquid ring pump according to the invention;

FIG. 2 is a partially sectional view taken along the line 2—2 in the direction of the arrows in FIG. 1 illustrating the pump of FIG. 1 provided with a single lobe;

FIG. 3 is a partially sectional view illustrating the pump of FIG. 1 provided with a double lobe;

FIG. 4 is a partially sectional view taken along the line 4—4 in the direction of the arrows in FIG. 5;

FIG. 5 is a partially sectional view of the rotor blade of the pump of FIG. 1; and

FIG. 6 is a sectional perspective view of the rotor blade of the pump showing its relationship to suction and discharge port members.

DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

A liquid ring pump constructed in accordance with the invention is shown in FIG. 1 consisting of a multi-bladed rotor **11** which is secured to shaft **12** by means of a keyway **13**, lock nut **14** and washer **15**. The shaft **12** is provided with sleeve **16** at the area of the mechanical seal assembly **17**. The rotor **11** rotates freely within casing **18** which forms one or more lobes **19** depending on the design which are eccentric to the rotor centerline. The rotor rotates around a port cylinder **20** on which sleeve **21** is secured. The port cylinder **20** is secured to the casing **18** and is held stationary.

The casing **18** is bolted to the suction member, or head **22** which is shown bolted to motor **23**. The head is provided with gas inlet connection **24**, seal water inlet connection **25**, and suction gas manifold **26** which connects to suction port **27**. The suction port **27** is cast or machined through the wall **28** of suction member or head **22**. The wall **28** could be a separate plate if desired. The wall **28** is in close, or sliding, contact with the open end of rotor blades **29**. The rotor blades **29** are also in close or sliding contact with the port cylinder sleeve **21** which is provided with a discharge port **30**. The discharge port **30** in the sleeve is matched to port opening **31** in the port cylinder **20**. The port cylinder is provided with a wall **32** at one end and the other end is open to the discharge connection **33** on the casing.

In operation water is introduced into the pump through seal water inlet **25** and through conduit **25a** to the seal chamber **34** where it provides cooling and lubrication for mechanical seal **17**. The water passes into the pump lobe **19** through clearance **35** between the wall **28** and the rotor **11**. As the rotor **11** is rotated the centrifugal forces cause the liquid to form a ring **36** conforming to the shape prescribed by the lobe **19**.

Referring to FIG. 2, where a single lobe configuration is shown, as the liquid ring is alternately cast away from and forced into the center of the rotor **11** the effect is to create liquid pistons formed by the interior surface **37** of the liquid ring confined by the rotor blades **29**, the rotor shroud **38** and the port plate **28**. The liquid pistons create air pockets **39** which are transported from the suction port **27** to the discharge port **30**. During the cycle the gas is compressed and the heat of compression is absorbed in the liquid ring **36**.

The action of the liquid ring **36** within the lobe **19** creates a flow of gas into the inlet **24** to manifold chamber **26** from which it is drawn into the rotor air pockets **39** through suction port **27**. The gas, with some of the liquid seal, is compressed and forced through the discharge ports **30** and **31** into the port cylinder discharge chamber **33a** and then out to discharge through discharge connection **33**.

As can be seen from the above description, the low pressure areas are kept segregated from the high pressure areas so that slippage losses are minimal. Close clearances are maintained between the rotor **11** and port plate **28**. Also, close clearances are maintained between sleeve **21** and the inner bore **40** of the rotor **11**.

In FIG. 3 a two lobe configuration is shown and like parts are given the same identifying numeral as in FIG. 2 but followed in each instance with a "prime." The teaching of the invention can be extended to any number of lobes. It is noted that in the two-lobe arrangement the suction ports **41** and **42** are located **180** degrees apart, as are discharge ports **43, 44** and **45, 46**. Thus, a pumping cycle takes place in 180° instead of 360° as in the single lobe design. A significant advantage of the invention is that regardless of the number of inlet and discharge ports, no special intricate conduits or passages are required. In FIG. 3 both suction ports **41** and **42** connect with a common suction chamber such as **26** as shown in FIG. 1, and both discharge ports **44** and **46** connect with a common discharge chamber such as **33** as shown in FIG. 1.

As disclosed herein rotor blades **29** are formed in the normal manner as shown in FIG. 2 with blades contacting the suction port **27** and discharge port **30** at 90° from direction of rotation. Also it is noted that rotor blades **47** shown in FIGS. 3, 4 and 5 form an angle at the point of contact between blade **47** and port plate **28** and port cylinder sleeve **21**. As the blade rotates its forward leading edge **50** passes inlet port **27** at close clearance. The angle is designed with optimum pitch so as to cut through the inlet fluid and direct the fluid into the bucket air space **39**. The angle of attack gives velocity to the fluid, driving it into the air space **39** formed by the receding liquid ring. The trailing surface **48** is curved and makes an angle B with the port plate **28**. The blade velocity creates a vacuum at the surface **48** which assists in sucking air or gas into the following air space **39**. Thus, the suction characteristic of the pump is improved, shock diminished, and noise level reduced substantially.

On the compression stroke the leading edge **49** of the blade **47** formed at the inner bore of the rotor **11** is angled away from the direction of rotation as described by angle **0**. As the blade **47** travels over port cylinder sleeve **21** in close clearance the liquid ring **36** forces the air or gas radially inward and as the gas is forced into the discharge port **30** its travel conforms to the curvature of the blade **47** at the point of exit **49**. This gradual change of direction creates a smoother fluidic flow than would an abrupt sharp ninety degrees shear, and the shock and noise level is substantially reduced. The back curving blade creates a lowered pressure which assists in the discharge of gas or air from the air space **39** in the following rotor bucket.

In summary, the forward curvature on the suction segment of the blade assists in sucking gas into the rotor buckets. The backward curvature on the discharge segment of the blade assists in the discharge of fluid from the rotor buckets. The benefits of this arrangement are lower noise level, higher efficiency, and better wear resistance due to smoother fluid flow.

Referring to FIG. 4 another feature of the invention is the use of guide vanes 51 in the port opening 27. The vanes 51 are formed by an angle less than 90° in the direction of rotation of the rotor as described, their purpose being to direct fluid flow so that the direction conforms closely to the angle at the leading edge 50 of rotor blade 29.

Referring to FIGS. 5 and 6, another feature of the invention is the use of guide vanes 52 in the discharge port opening 30. The vanes 52 are formed by an angle less than ninety degrees in the direction of rotation of the rotor as described, their purpose being to direct fluid flow radially inward thereby reducing shock caused by fluidic shear. This action assists in directing the fluid through port openings 30 and out to discharge.

I claim:

1. A liquid ring pump including in combination a casing, a rotor shaft supported in said casing, a rotor supported by said rotor shaft, blades of said rotor having first and second opposite blade edges, a suction head, a radially projecting wall of said head with which said first blade edges are in sliding contact, wall ports of said wall, pump inlet means in communication with said wall ports, radially projecting shroud means integral with said second blade edges which are in sliding contact with an axially disposed central member mounted radially inward of said rotor and about which said rotor can rotate, central member ports of said central member, pump discharge means in communication with said central member ports, a lobe of said casing, means for rotating said rotor whereby a fluid material is drawn from said pump inlet means, through said wall ports and within said casing and discharged through said central member ports and said pump discharge means and liquid inlet means whereby upon rotation of said rotor liquid is introduced into said casing within said lobe to be contacted by said fluid material upon passage therethrough and in which first angled guide vanes in said pump inlet means are provided in combination with second angled guide vanes in said pump discharge means so that fluid flow is directed at an angle less than 90 degrees from the surface of said wall and said central member respectively and in the direction of the communicating rotor blades.

2. A pump as set forth in claim 1 in which a ported sleeve is located on said central member between said central member and said rotor with the ports thereof in communication with the blades of the rotor.

3. A pump as set forth in claim 1 in which said rotor shaft is disposed in an internal chamber, and said liquid inlet means includes a conduit connected from said chamber to external liquid source, said chamber being isolated from said pump inlet and discharge means.

4. A liquid ring pump including in combination a casing, a rotor shaft supported in said casing, a rotor supported by said rotor shaft, blades of said rotor having first and second opposite blade edges, a suction head, a radially projecting wall of said head with which said first blade edges are in sliding contact, wall ports of said wall, pump inlet means in communication with said wall ports, radially projecting shroud means integral with said second blade edges which are in sliding contact with an axially disposed central member mounted radially inward of said rotor and about which said rotor can rotate, central member ports of said central member, pump discharge means in communication with said central member ports, a lobe of said casing, means for rotating said rotor whereby a fluid material is drawn from said pump inlet means, through said wall ports and within said casing and discharged through said central member ports and said pump discharge means and liquid inlet means whereby upon rotation of said rotor liquid is introduced into said casing within said lobe to be contacted by said fluid material upon passage therethrough and in which said blades are contoured such that blade edges at areas in communication with said wall ports are directed forward in the direction of rotation so as to provide a pitch angle less than 90° at point of contact with incoming fluid material.

5. A liquid ring pump including in combination a casing, a rotor shaft supported in said casing, a rotor supported by said rotor shaft, blades of said rotor having first and second opposite blade edges, a suction head, a radially projecting wall of said head with which said first blade edges are in sliding contact, wall ports of said wall, pump inlet means in communication with said wall ports, radially projecting shroud means integral with said second blade edges which are in sliding contact with an axially disposed central member mounted radially inward of said rotor and about which said rotor can rotate, central member ports of said central member, pump discharge means in communication with said central member ports, a lobe of said casing, means for rotating said rotor whereby a fluid material is drawn from said pump inlet means, through said wall ports and within said casing and discharged through said central member ports and said pump discharge means and liquid inlet means whereby upon rotation of said rotor liquid is introduced into said casing within said lobe to be contacted by said fluid material upon passage therethrough and in which said blades are contoured such that blade edges at areas in communication with said central member ports are directed back away from the direction of rotation so as to provide a discharge pitch angle less than 90° at a point of contact with discharged fluid material.

6. A liquid ring pump including in combination a casing, a rotor shaft supported in said casing, a rotor supported by said rotor shaft, blades of said rotor having first and second opposite blade edges, a suction head, a radially projecting wall of said head with which said first blade edges are in sliding contact, wall ports of said wall, pump inlet means in communication with said wall ports, radially projecting shroud means integral with said second blade edges which are in sliding contact with an axially disposed central member mounted radially inward of said rotor and about which said rotor can rotate, central member ports of said central member, pump discharge means in communication with said central member ports, a lobe of said casing, means for rotating said rotor whereby a fluid material is drawn from said pump inlet means, through said wall ports and within said casing and discharged through said central member ports and said pump discharge means and liquid inlet means whereby upon rotation of said rotor liquid is introduced into said casing within said lobe to be contacted by said fluid material upon passage therethrough and in which said blades are contoured such that blade edges at areas in communication with said wall ports are directed forward in the direction of rotation so as to provide a pitch angle less than 90° at point of contact with incoming fluid material and blade edges at areas in communication with said central member

ports are directed back away from the direction of rotation so as to provide a discharge pitch angle less than 90 degrees at point of contact with discharged fluid material.

7. A pump in accordance with claim 4 having angled guide vanes in said pump inlet means to direct fluid flow such that flow is directed at an angle less than 90° from the surface of said plate in the direction of the communicating rotor blades.

8. A pump as set forth in claim 5 having angled guide vanes in said pump discharge means to direct fluid flow such that flow is directed at an angle less than 90° from the central member and in the direction of the communicating rotor blades.

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