

[54] MULTI-STAGE REGENERATIVE FLUID PUMP

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- [52] U.S. Cl. 415/53 T; 415/101; 415/213 T
 [51] Int. Cl.² F04D 5/00; F04D 1/04
 [58] Field of Search..... 415/52, 76, 92, 53 T, 152,
 415/202, 213 T, 101, 102, 103; 416/97

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Primary Examiner—C. J. Husar

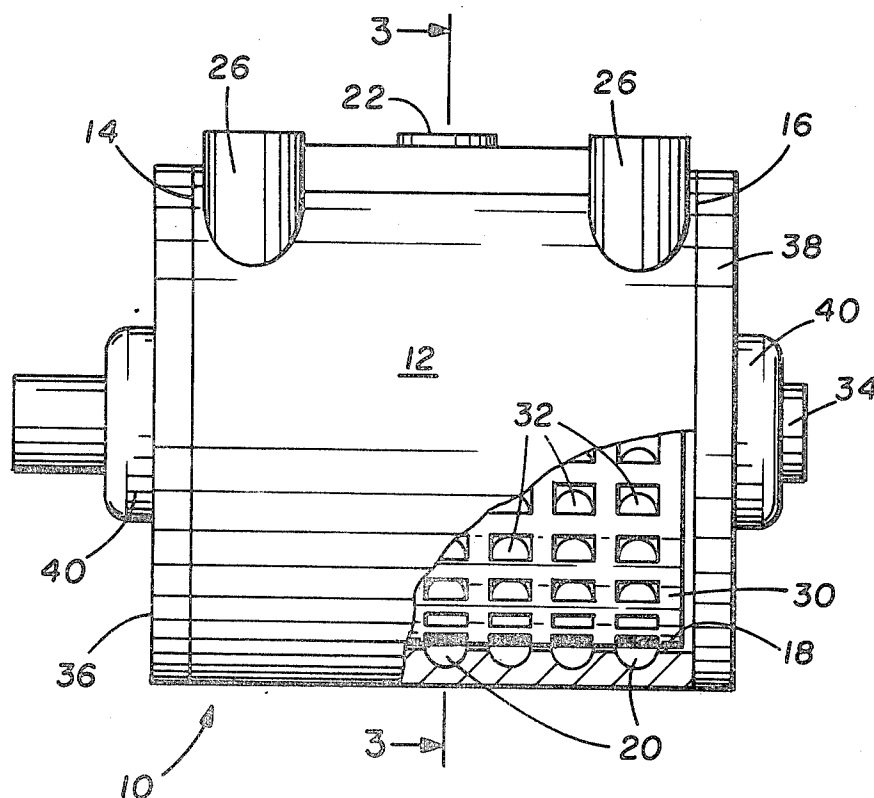
Assistant Examiner—Louis J. Casoregola

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[57] ABSTRACT

A regenerative fluid pump is described hereinafter that is capable of being operated as a vacuum pump or as a compressor. The pump is a multi-stage device and contains no seals in the conventional sense between stages. Further, the pump consists of a housing having a cylindrical bore with a cylindrical rotor rotatably located therein. The rotor operates with relatively close tolerance within the bore. End plates mounted on the housing to serve journal the rotor and to close the ends of the bore. The rotor is provided on its periphery with a plurality of rows of pockets and the interior of the housing is provided with a plurality of grooves that are in registration with the rows of pockets in the rotor. Relatively short transfer grooves extend between the rows of grooves to provide for flow of the fluid from one row to the other.

2 Claims, 8 Drawing Figures



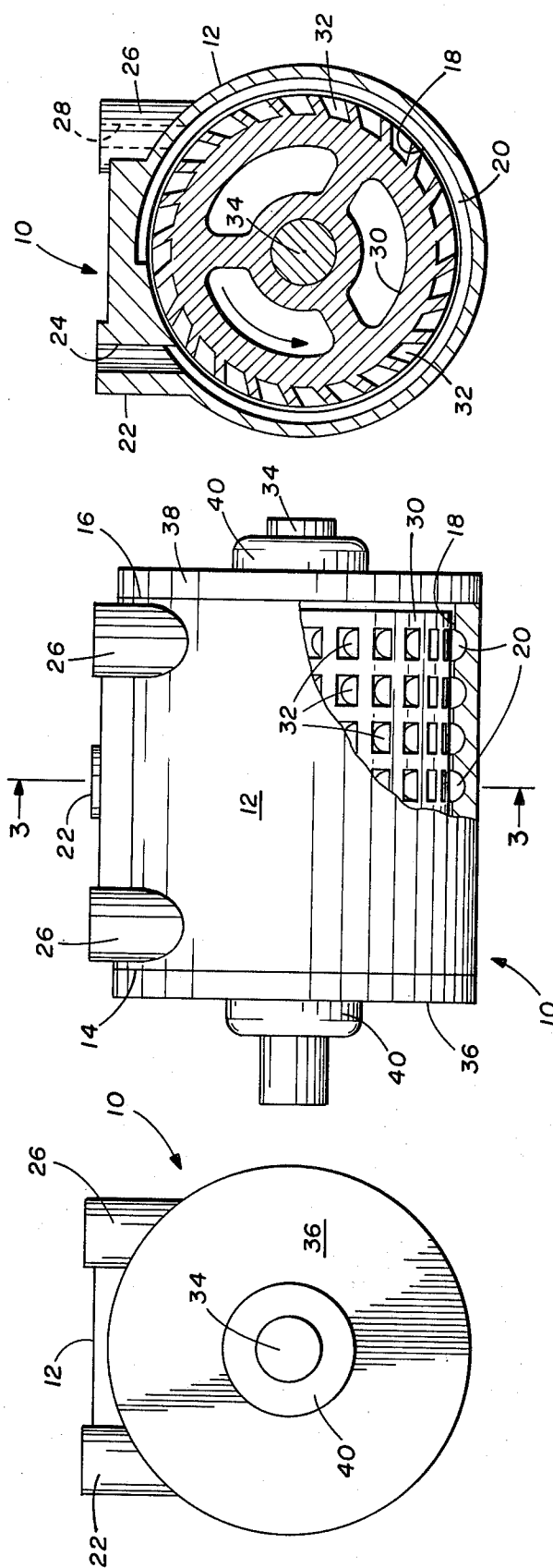


FIG. 3

FIG. 1

FIG. 2

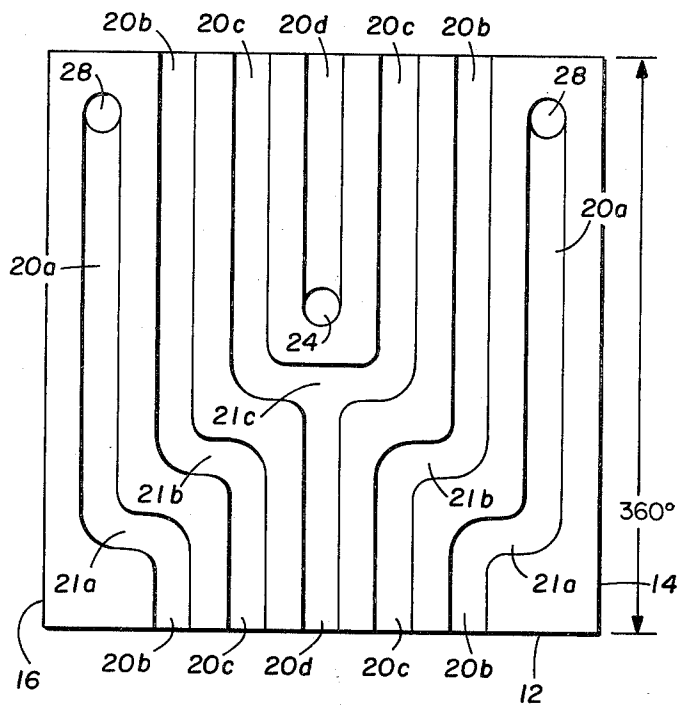


FIG. 4

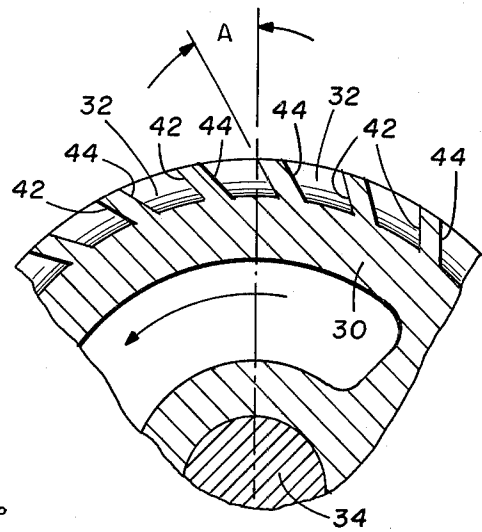


FIG. 5

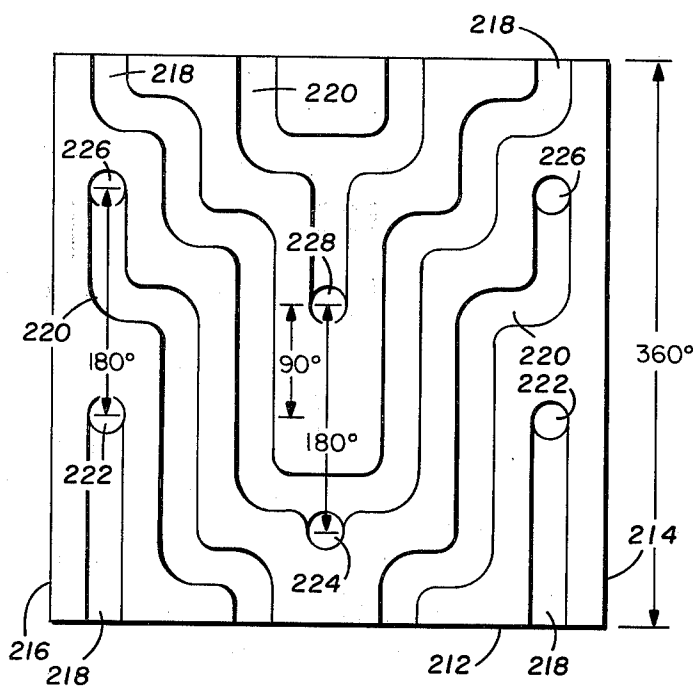


FIG. 7

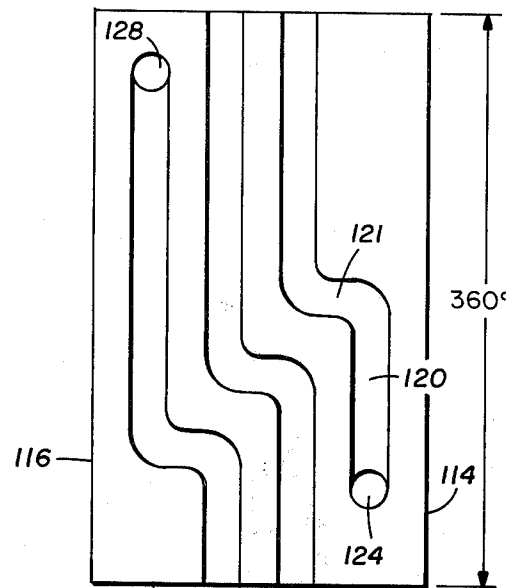


FIG. 6

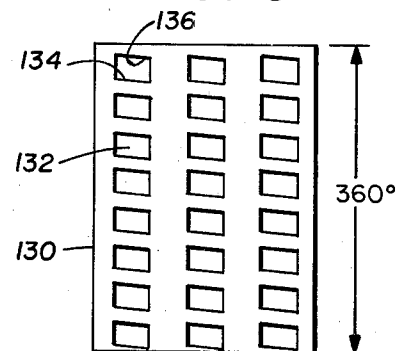


FIG. 8

MULTI-STAGE REGENERATIVE FLUID PUMP

BACKGROUND OF THE INVENTION

This invention relates generally to fluid pumps. More particularly, but not by way of limitation, this invention relates to an improved multi-stage regenerative fluid pump that is useful as a compressor or vacuum pump.

A number of patents have been issued describing somewhat similar apparatus, but for the most part, they have been intended for use as engines or motors being driven by the fluid flowing therethrough and, thus, utilize arrangements of flow passageways and rotor structures different from this invention as well as operating on the principle of frictional flow rather than regenerative flow. Among the patents issued on such apparatus are: U.S. Pat. No. 68,325, issued Aug. 27, 1867 to T. Welham; U.S. Pat. No. 511,964, issued Jan. 2, 1894, to F. B. Merrill; U.S. Pat. No. 1,031,834, issued July 9, 1912, Haentjens, to B. Brazelle; and U.S. Pat. No. 3,697,190 issued Oct. 10, 1972, to Walter D. Haentjens. All of the foregoing with the exception of the U.S. Pat. No. 1,031,834 describe apparatus having a helical flow path either in the rotor or in the casing. Such devices are not capable of multi-stage regenerative flow due to the random incident of the rotor flow path matching that of the housing. U.S. Pat. No. 1,031,834 is a single-stage engine not capable of regenerative flow.

It is an object of this invention to provide an improved regenerative fluid pump having multiple stages and capable of use as a compressor or vacuum pump.

Another object of the invention is to provide an improved multi-stage, regenerative fluid pump that does not require seals between the stages nor does it require seals between the end of the rotor and housing.

A further object of the invention is to provide an improved multi-stage, regenerative fluid pump of very simple construction that will require little or no maintenance during its normal operating life.

SUMMARY OF THE INVENTION

This invention provides a multi-stage regenerative fluid pump comprising a generally cylindrical rotor having a plurality of pockets encircling the outer periphery thereof with the pockets being arranged in a plurality of spaced rows extending generally parallel to the ends of the rotor. The pump also includes a housing having a generally cylindrical bore therethrough sized to closely receive the rotor. Formed in the inner periphery of the housing are a plurality of spaced grooves that partially encircle the bore and that are arranged in registration with the rows of pockets in the rotor. Means are provided for connecting the grooves with each other and with inlet and outlet ports that extend through the housing. Each end of the housing is closed by an end closure member that also functions to rotatably support the rotor.

The foregoing and additional objects and advantages of the invention will become more apparent as the following detailed description is read in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a view, partly in elevation and partly in cross section, illustrating a fluid pump constructed in accordance with the invention.

FIG. 2 is an end elevation view of the pump of FIG. 1.

FIG. 3 is a cross-sectional view of the pump of FIG. 1 taken generally along the line 3—3 of FIG. 1.

FIG. 4 is a layout illustrating the arrangement of the grooves formed in the housing of the pump of FIG. 1.

FIG. 5 is an enlarged cross-sectional view of a portion of the rotor of the pump of FIG. 1, illustrating the structure of the pockets in more detail.

FIG. 6 is a layout of another arrangement of grooves that may be utilized in a pump constructed in accordance with the invention.

FIG. 7 is a layout of an additional groove arrangement that may be utilized in a pump also constructed in accordance with the invention.

FIG. 8 is a layout illustrating the outer periphery of another embodiment of rotor that may be used in a pump constructed in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing and to FIGS. 1, 2, and 3 in particular, shown therein and generally designated by the reference character 10 is a multi-stage regenerative fluid pump. The pump 10 includes a housing 12 having ends 14 and 16 and a generally cylindrical bore 18 that extends therethrough intersecting the ends 14 and 16. The housing 12 has a plurality of grooves 20 formed therein adjacent to the bore 18. The grooves 20 will be described in more detail in connection with the description of FIG. 4.

A boss 22 is provided on the housing 12 through which a port 24 extends. The port 24 extends into the bore 18 as may be seen in FIG. 3 and is provided at its upper end with suitable threads, flanges, etc., (not shown) for connection with a conduit (not shown) as required.

Similarly, the housing 12 is provided with a pair of bosses 26 that are spaced from the boss 22. The bosses 26 are each provided with a port 28 (shown in dash lines in FIG. 3) that extend through the housing 12 into the bore 18.

A rotor 30 is positioned in the bore 18 and includes an outer periphery having a plurality of rows of pockets 32 thereon. The rows of pockets 32 are arranged in alignment or in registration with the annular grooves 20 formed in the housing 12. The pockets will be described more completely in connection with the description of FIG. 5.

The rotor 30 includes a shaft 34. The shaft 34 extends through end plates 36 and 38 that are attached to the housing 12 to close the ends of the bore 18. The end plates 36 and 38 are provided with bearings 40 and 42 to rotatably support the rotor 30 in the bore 18. The ends of the rotor 30 are disposed very close to the inside of the end plates 36 and 38 and the outer periphery of the rotor 30 fits closely within the bore 18 to eliminate the necessity for seals between the rotor and the housing 12 and between the rotor 30 and the end plates 36 and 38. Seals can be used if desired.

FIG. 4 shows a layout for an arrangement of the grooves 20 that is suitable for use in the pump 10 illustrated in FIG. 1. It will be observed that if FIG. 4 is viewed as having a vertical center line, the right and left end portions thereof are mirror images. Previously described ports 28 are located at the upper right-hand and left-hand corners of FIG. 4. Extending downwardly from the ports 28 are grooves 20a that extend for al-

most the full circumference of the bore 18 and that are disposed generally parallel to the ends 14 and 16. Extending parallel to the grooves 20a are a pair of grooves 20b which are connected to the grooves 20a by a cross-over groove 21a. It will be noted that the grooves 20b also extend for almost the entire circumference of the bore 18.

Grooves 20c are located parallel to the grooves 20b and 20a and are connected to the grooves 20b by cross-over groove 21b. The grooves 20c are parallel to and connected to a groove 20d by the cross-over groove 21c. The groove 20d extends almost around the entire circumference of the bore 18 terminating at the port 24. Each of the grooves 20 preferably has a cross-section that is somewhat elliptical in configuration as illustrated in FIG. 1. The precise configuration is not critical, but may cause some variation in the overall efficiency of the pump 10.

FIG. 5 is a partial cross-sectional view illustrating in more detail the structure of the rotor 30 and the pockets 32 formed therein. The pockets 32 are preferably of elliptical cross-section matching the cross-sectional configuration of the grooves 20. Each of the pockets 32 defines a leading wall surface 42 and a trailing wall surface 44. In the preferred configuration, the angle A shown in FIG. 5 is about 30° as measured from a plane extending through the axial centerline of the rotor 30. With slightly less efficiency, the angle A may vary from about 0° up to a maximum of about 60°.

The trailing wall surface 44 is preferably disposed generally parallel to the leading wall surface 42. However, the exact angle of the trailing wall surface 44 is not critical but is believed to produce better regenerative flow characteristics if it is parallel to the wall surface 42.

OPERATION OF THE PREFERRED EMBODIMENT

As shown in FIG. 3, the rotor 30 is located in the housing 12 in an arrangement suitable for utilizing the pump 10 as a vacuum pump. With the port 24 connected to the chamber in which the vacuum is to be drawn, the rotor 30 is caused to rotate in the direction of the arrow shown in FIG. 3. As the pockets 32 pass the port 24, fluid is drawn into the pump 10 through the port 24 and carried with the rotor through the grooves 20 to the port 28.

In FIG. 4, the arrangement is such that fluid will be drawn in through the port 24 and driven through the grooves 20d, 20c, 20b, 20a, and outwardly through the ports 28. As will be readily apparent from that figure, the highest vacuum occurs in the region of the port 24 with the fluid being discharged through the port 28 at a much higher pressure. Accordingly, it is not necessary to provide fluid-tight seals across the pump 10 due to the pressure gradation across the housing 12 and rotor 30 from the port 24 to the ports 28.

The necessity for seals along the ends of the rotor 30 adjacent the ends 14 and 16 of housing 12 is substantially eliminated since the pressure in grooves 20a will be at or near atmospheric.

Regenerative flow occurs due to the rotational speed of the rotor 30 which discharges fluid centrifugally out of the pockets 32 into the grooves 20. The fluid being driven out into the grooves 20 rotates back into the pockets 32. Simultaneously, the fluid is being carried along the length of the grooves 20 by the rotor 30 and as a result, the flow describes a spiral through the grooves 20 into and out of the various pockets 32.

The foregoing described flow can occur in the pump 10 due to the registration or coincidence of the grooves 20 and the rows of pockets 32 in the rotor 30. In devices wherein the flow path or the grooves are formed on a helix, the regenerative flow pattern cannot be maintained, but, rather, frictional flow occurs.

Experimental work performed on the relative merits of frictional flow versus regenerative flow, indicates that regenerative flow produces a pressure drop characteristic many, many times higher than the pressure drop due to frictional flow.

If it is desirable to use the pump 10 as a compressor, the rotor 30 is removed from the housing 12 and turned end for end and replaced in the housing 12. The rotor 30 is then driven in the opposite direction so that the fluid is drawn into the pump 10 through the ports 28 passing through the grooves 20a, 20b, 20c and 20d and outwardly through the port 24. Each of the grooves acts as a separate stage of a compressor, so that between each groove there will be a pressure rise as the pump 10 is used as a compressor. Again, it is not necessary to provide an absolute seal between rows since the higher pressure occurs at the port 24 which is located approximately midway of the housing 12 in the pump 10. The pressure near the ends of the rotor 30 will be substantially atmospheric resulting in very low leakage losses.

It should be pointed out that the rotor 30 can be rotated at extremely high speeds because there is no contact with the housing 12 or with the end members 36 and 38. Thus, the only heat generated during the operation of the pump 10 results from the friction of the fluid moving through the pump.

Housing Modification of FIG. 6

The layout of FIG. 6 illustrates a modification of the housing designated by the reference character 112. It will be understood that the rotor will be correspondingly modified.

The housing 112 includes ends 114 and 116, a port 124 and a port 128 extending through the housing 112, and a plurality of rows of grooves 120 formed in the housing 112. The rows extend in generally parallel relationship to the ends 114 and 116. Cross-over grooves 121 are provided to permit flow through the grooves 120 from the port 124 to the port 128.

The modified form of the pump incorporating the housing 112 can be utilized either as a blower or a vacuum pump as was true with the pump 10. However, since the pressure rise occurs from one end to the other, an axial thrust is developed in the modified form of the pump. The axial force generated can be relatively easily compensated for by the provision of a thrust bearing or shoulder on the rotor shaft.

Housing Modification of FIG. 7

The layout of FIG. 7 illustrates another arrangement of grooves formed in a modified housing 212. The housing 212 includes ends 214 and 216. It will be understood that a rotor will be correspondingly modified.

As was true of the layout of FIG. 4, the groove arrangement in FIG. 7 is also a mirror image on left and right hand sides of a vertical centerline taken through FIG. 7. The housing 212 includes two sets of grooves 218 and 220. The grooves 218 extend between ports 222 and a single port 224. The grooves 220 extend between ports 226 and a single port 228.

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As shown on the layout of FIG. 7, the ports 222 and 226 are disposed at an angle of 180° relative to each other. Similarly, the ports 224 and 228 are disposed at an angle of 180° relative to each other. As will be appreciated, the ports 222 and 226 and the ports 224 and 228 lie on diametrically opposed sides of the housing 212. Thus, any pressure forces developed in the modified form of the pump incorporating the housing 214 will have balanced radial forces on the rotor. Such an arrangement is particularly advantageous if the pressures developed in the pump are relatively high.

Rotor Modification of FIG. 8

The layout of FIG. 8 illustrates a modification of the rotor that is designated by the reference character 130. As can be clearly seen, the pockets 132 are formed in rows extending around the circumference or outer periphery of the rotor 130. The rows of pockets 132 are disposed generally parallel with the ends of the rotor 130.

The modification consists of forming the pockets 132 in the rotor 130 so that they define a leading wall surface 134 that is disposed at an angle relative to the centerline of the rotor. As mentioned in connection with the rotor 30, it is desirable, but not required, to form the trailing wall surface 136 parallel to the leading wall surface 134.

It will be appreciated that the pockets 132 are skewed slightly relative to the axial centerline of the rotor 130. Upon rotation of the rotor 130, the leading wall surfaces 134 tend to encourage the spiraling of the fluid through the pockets 132 and the corresponding grooves in the housing in which the rotor 130 is positioned. The number of rows of pockets 132 are exemplary only. It will be understood that the rotor 130 and the housing in which the rotor is mounted will have corresponding grooves and rows of pockets.

While specific embodiments and modifications have been described in detail hereinbefore, it will be understood that many changes and modifications can be

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made thereto without departing from the spirit of the invention. For example, the precise number of stages, the shape of the grooves, and the configuration of the pockets can be varied within the purview of the invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A regenerative fluid pump comprising:

a generally cylindrical rotor having a plurality of pockets encircling the outer periphery thereof, said pockets being disposed in a plurality of spaced rows arranged generally parallel to the ends of said rotor, each said pocket defines a leading wall surface on said rotor that is disposed at an acute angle relative to the center-line of said rotor;

a housing having first and second ends, a generally cylindrical bore extending therethrough intersecting said first and second ends and sized to closely receive said rotor, a first port extending through said housing into said bore, a pair of second ports extending through said housing into said bore and located closer to said first and second ends than said first port, a plurality of spaced grooves in said housing and partially encircling said bore and arranged generally parallel to said first and second ends, each said row being in radial alignment with a respective row of pockets in said rotor, and means for connecting said grooves to provide communication between said first port and each said second port; and, end closure means for closing each end of said bore and rotatably supporting said rotor, whereby rotation of said rotor causes fluid to flow through said pump via said ports and grooves.

2. The regenerative fluid pump of claim 1 wherein each said pocket defines a leading wall surface on said rotor that is disposed at an acute angle relative to a radially extending plane projected through the center-line of said rotor.

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