Feb. 7, 1950 J. M. ROTH ET AL 2,496,496

TURBINE PUMP

Filed Feb. 15, 1946 2 Sheets-Sheet 1

Fig. 1.

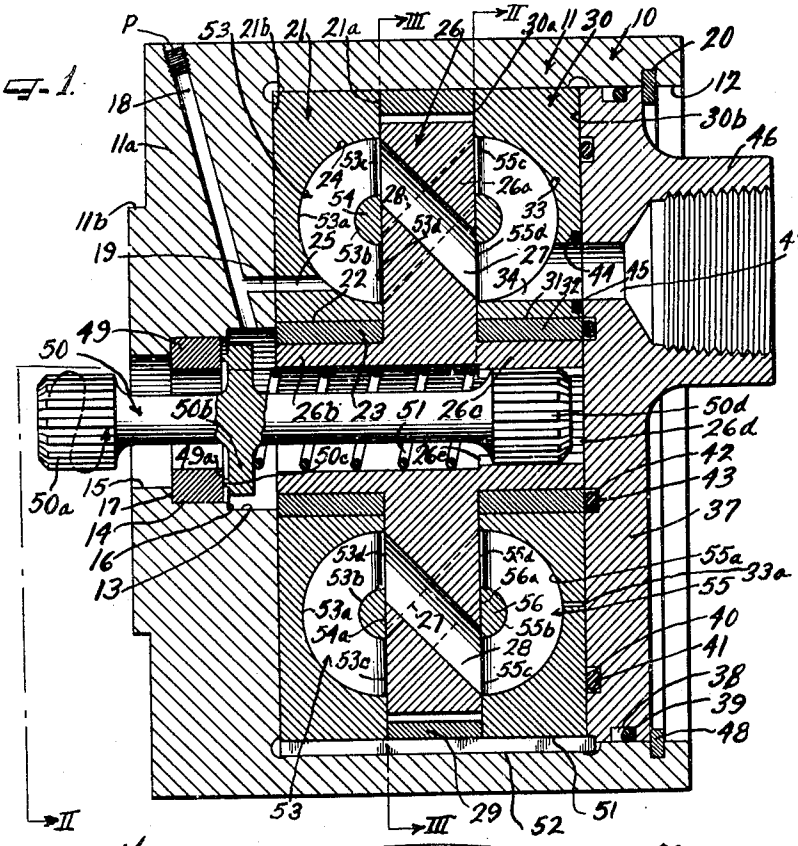


Fig. 4.

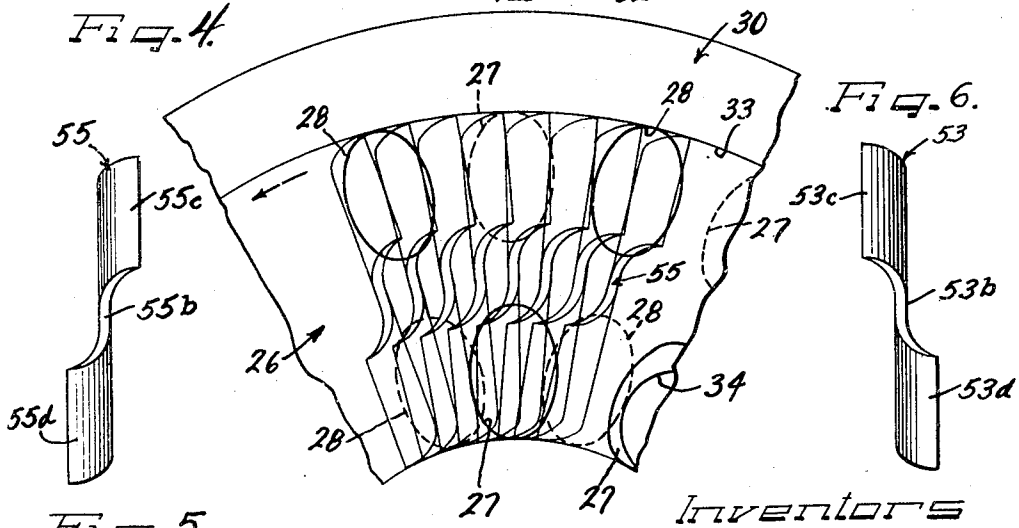


Fig. 5.

Fig. 6.

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Fig. 2.

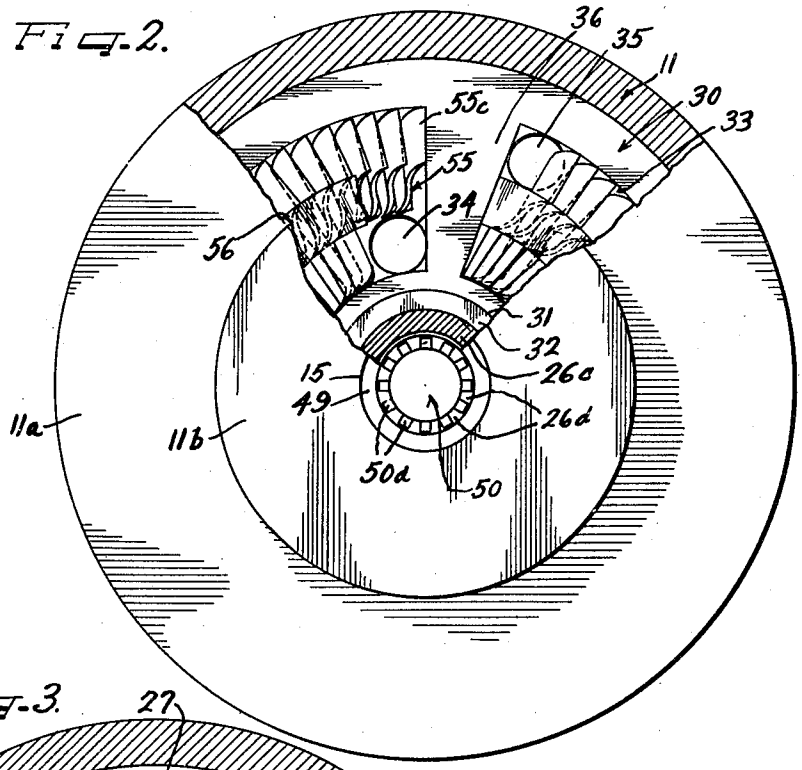
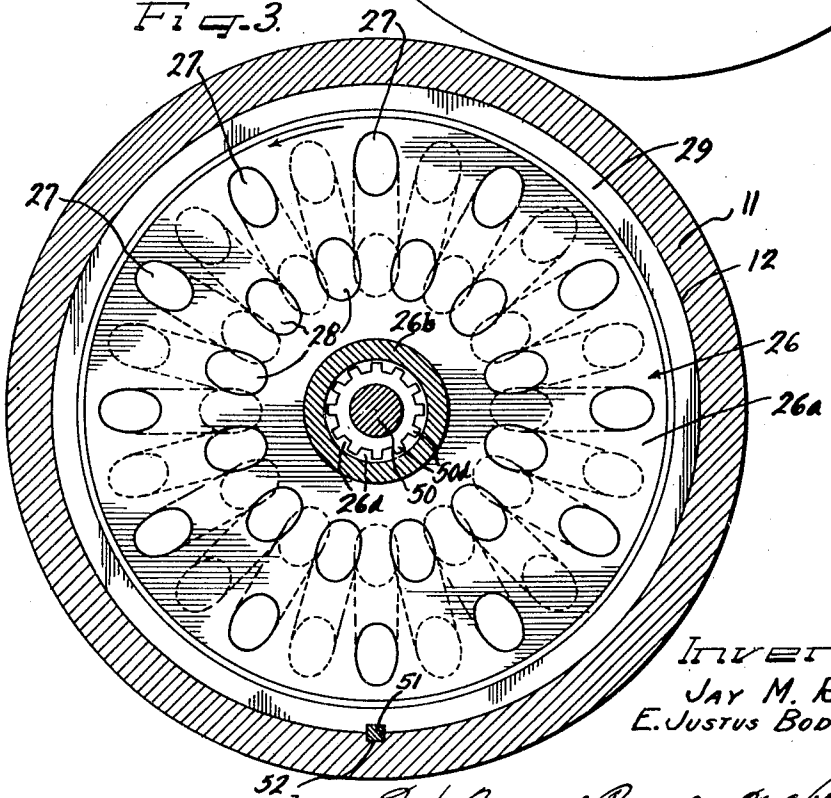


Fig. 3.



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UNITED STATES PATENT OFFICE

2,496,496

TURBINE PUMP

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Application February 15, 1946, Serial No. 647,757

14 Claims. (Cl. 103—109)

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This invention relates to turbine pumps for building up high pressures at relatively low rates of flow without requiring excessive driving effort.

Specifically, the invention deals with a turbine pump having a rotor with fluid passages at spaced intervals around the periphery thereof and stator vanes alongside of the rotor for directing fluid flow to the inner ends of the rotor passages and out of the outer ends of the rotor passages in such a manner as to produce a series of incremental pressure boosts or increases of pressure on the fluid to obtain an efficient multi-stage pump-the effect on the fluid.

Heretofore, turbine pumps have included impeller wheels or rotors running in a continuous channel or race having a barrier only between the inlet and outlet ports of the pump. In such turbine pumps, a continuous ring of fluid surrounds the rotor in the pumping channel or race, and is subjected to a number of impacts or impulses by the rotor vanes to be forced for substantially a complete revolution in the channel between the inlet and outlet ports. The impacts or impulses given to the fluid by the blades of the rotor produce a multi-stage pumping effect but, since no dividing walls are provided in the channel or race between the inlet and outlet ports of the pump, all of the stages of the pump are in full communication with each other around the entire periphery of the rotor and the pressure increase obtained in each stage is, therefore, necessarily quite small. Further, in such pumps, both sides of the rotor or impeller are exposed to the same pumping channel or race, and fluid advances in parallel communicating paths on opposite sides of the impeller and is at the same pressure in each path at any particular section of the channel. The pressure build-up thereby produced by the pump is thus limited to the number of impacts or impulses that can be given to the fluid in a single continuous channel or race. Thus, while known turbine pumps develop higher pressures than are obtainable in centrifugal pumps having equal impeller diameters and operating at the same speeds, prior to this invention turbine pumps were incapable of efficiently developing such high pressures at very low delivery rates.

According to the present invention, a high pressure, low delivery turbine pump is provided in a very compact, lightweight arrangement suitable for use in aircraft. The pumps of this invention are capable of developing from 500 to 1000 lbs. per square inch pressure on fluids such as gasoline

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at low delivery rates and are especially useful to feed the jets of gas turbine fuel systems.

The pumps of this invention have fluid-directing stator vanes arranged alongside of the rotor to guide the fluid and to actually separate the pumping channel or race into a plurality of individual effects or stages. These stator vanes receive fluid centrifugally discharged from the outer ends of the rotor passages and guide the fluid to the inner ends of the rotor passages at advanced points in the pumping channel. A definite multi-staged pumping effect is thereby obtained.

A feature of the invention resides in the provision of fluid-directing vanes on opposite sides of the rotor in the pumping channel or race of a turbine pump, and the provision of alternate oppositely inclined bores through the rotor at spaced intervals therearound and each having an outer end discharging through one side face of the rotor and an inner end receiving fluid through the opposite side face of the rotor. Fluid is discharged by centrifugal force from the outer ends of the bores and is directed by the vanes into the inner ends of the oppositely sloping adjacent bores for further staging or pumping back to the outer ends of these bores. A criss-cross staging of the fluid is thereby obtained to produce a series build-up of pressure in alternating stages on opposite sides of the rotor. In effect, two separate vaned pumping channels are provided, one on each side of the rotor, but pumping progresses alternately from one channel to the other in series of stages. Higher pressures at lower rates of flow are thereby obtained.

It is, then, an important feature of this invention to provide a turbine pump wherein fluid is circulated in series back and forth to opposite sides of the pump rotor, thereby eliminating the heretofore parallel operation of both sides of a conventional turbine pump to increase the pressure developed by turbine pumps and, at the same time, to substantially balance thrust loads on the rotor.

Another feature of the invention resides in the provision of stator vanes or fluid flow-directing vanes in the pumping channel or race of a turbine pump to separate the pumping channel or race into definite pumping stages.

A still further feature of the invention is to provide a pump rotor with criss-crossed bores to define fluid flow pumping channels in a pump operating on a turbine principle.

A still further feature of the invention is to provide a pump seal subjected to pump discharge

pressures but vented back to a selected lower pressure area of the pump for limiting the pressure on the seal.

An object of the invention is to increase the discharge pressure capacity of turbine-type pumps without increasing the flow rate of the pump.

Another object of the invention is to provide a series type turbine pump that will develop very high pressures at very low delivery rates.

A still further object of the invention is to provide a small, lightweight, compact turbine pump suitable for aircraft usage and capable of developing sufficiently high pressures at low delivery rates for supplying the feed jets of an aircraft turbine engine.

A still further object of the invention is to provide a turbine pump with stator vanes or guide vanes coacting with the pump rotor in the pumping channel or race of the pump for dividing the race into distinct pumping stages.

A still further object of the invention is to provide a pump seal arrangement for high pressure pumps that is maintained at a predetermined pressure less than the full pressure developed by the pump.

Other and further objects of the invention will be apparent to those skilled in the art from the following detailed description of the annexed sheets of drawings which, by way of a preferred example only, illustrate one embodiment of the invention.

On the drawings:

Figure 1 is an axial cross-sectional view, with parts in elevation, of a turbine pump according to this invention.

Figure 2 is a transverse cross-sectional view, with parts in end elevation, taken substantially along the line II—II of Figure 1 and having some parts broken away to show underlying structure.

Figure 3 is a transverse cross-sectional view taken substantially along the line III—III of Figure 1.

Figure 4 is a fragmentary phantom diagrammatic view illustrating operation of the pump of Figures 1 to 3.

Figure 5 is a plan view of a stator vane for the right hand side of the rotor of the pump shown in Figure 1.

Figure 6 is a plan view of a stator vane for the left hand side of the rotor of the pump shown in Figure 1.

As shown on the drawings:

As best shown in Figure 1, the pump 10 of this invention includes a cylindrical metal casing 11 having a cylindrical bore 12 extending inwardly from its back face to a front or end wall 11*a*. The front wall 11*a* has a central forwardly projecting pilot portion 11*b* to center the casing in the aperture of a mounting pad of a motor (not shown) for driving the pump. This front wall 11*a* has a stepped bore through the central portion thereof including a major diameter bore portion 13 communicating with the chamber provided by the bore 12, an intermediate reduced bore 14 extending concentrically from the bore 13, and a smaller bore 15 extending concentrically from the bore 14 through the front face of the pilot portion 11*b*. A shoulder 16 is provided between the bores 13 and 14. A second shoulder 17 is provided between the bores 14 and 15.

A drilled hole 18 is formed through the front wall 11*a* of the casing 11 and communicates at its inner end with the chamber provided by the bore 13. The outer end of this hole 18 is closed

by a screw plug P threaded into the casing. A drilled hole 19 in the front wall or end wall 11*a* intersects the inner end of the hole 18 as shown for a purpose to be more fully hereinafter described.

A groove 20 is formed around the bore 12 of the casing 11 near the open rear end face of the casing for a purpose to be hereinafter more fully described.

A ring block 21 snugly fitting the bore 12 of the casing 11 is seated in the casing against the end wall 11*a* thereof. This ring block 21 has a central aperture 22 lined with a cylindrical bushing or bearing 23. This cylindrical bushing or bearing 23 is also bottomed on the end wall 11*a* of the casing 11.

The ring block 21 has an annular groove 24 of semicircular cross section between the aperture 22 and the periphery thereof. This groove 24 extends inwardly from the flat face 21*a* of the ring 21 which is opposite the flat face 21*b* seated on the end wall 11*a* of the casing. A hole 25 is provided through the ring block 21 to join the hole 19 with the groove 24 at a point in the pump near the inlet port thereof for a purpose to be more fully hereinafter described.

A rotor 26 having a flat faced circular disk or wheel portion 26*a* with central hollow hub portions 26*b* and 26*c* extending from opposite faces thereof is mounted in the bore 12 of the casing 11 with the hub 26*b* thereof rotatably supported in the bushing or bearing 23 carried by ring block 21 and with one flat face of the disk portion 26*a* thereof in close-running clearance relation with the face 21*a* of the ring block 21. The disk or wheel portion 26*a* of the rotor 26 is of smaller diameter than the bore 12 but of a sufficiently great diameter to extend radially beyond the groove 24.

The circular disk portion 26*a* of the rotor 26 has alternate oppositely inclined bores 27 and 28 therethrough around the peripheral portion thereof. The bores 28 register with the radially inner portion of the groove 24 in the ring block 21. The bores 27 have outer ends registering with the radially outer portion of the groove 24 in the ring block 21.

A spacer sleeve 29 is mounted in the bore 12 of the casing 11 and is bottomed on the face 21*a* of the ring block 21. This spacer sleeve 29 surrounds the disk portion 26*a* of the rotor 26 in spaced relation.

A second ring block 30 snugly fitting the bore 12 of the casing 11 is inserted through the open rear face of the casing 11 and is bottomed on the spacer sleeve 29. This sleeve 29 separates the ring blocks 21 and 30 to maintain desired operating clearance for the rotor disk portion 26*a* between the ring blocks.

The ring block 30 has a central aperture 31 therethrough lined with a cylindrical bushing or bearing 32. The hub 26*c* of the rotor is rotatably mounted in this bushing or bearing 32.

The ring block 30 has an annular groove 33 of semicircular cross section between the aperture 31 and the periphery thereof. This groove 33 extends inwardly from the flat face 30*a* of the ring block which is bottomed on the spacer sleeve 29. The holes 27 in the rotor disk 26*a* communicate at their inner ends with the radially inward portion of the groove 33 while the holes 28 through the rotor disk 26*a* communicate at their outer ends with the radially outward portion of the groove 33.

An inlet port 34 extends in an axial direction

through the bottom of the ring block **30** to communicate with the radially inward portion of the groove **33**.

As shown in Fig. 2, an outlet port **35** extends in an axial direction through the ring block **30** to communicate with the radially outward portion of the groove **33**. The inlet and outlet ports **34** and **35** are circumferentially spaced and a partition wall **36** extends radially across the groove **33** between the inlet and outlet ports to separate these ports. A similar partition wall (not shown) is provided in the groove **24** of the ring block **21** in axial alignment with the partition wall **36**.

A closure disk or end plate **37** is seated in the bore **12** of the casing **11** to close the back of the casing. A peripheral groove **38** is provided around the disk **37** to receive an "O" ring seal **39** for sealing the periphery of the disk **37**. A second groove **40** is provided around the inner face of the closure disk **37** to receive another "O" ring seal **41** to seal against the face **30***b* of the ring block **30**.

A third groove **42** is provided in the face of the ring **37** to receive a third "O" ring **43** for sealing against the bearing **32**.

The space between "O" rings **41** and **43** is open through holes such as **33***a* in the ring block **30** extending from the groove **33** at such pressure stages as is necessary to hold the ring blocks **30** and **21** tightly against the spacer **29**, thus maintaining close operating clearance between the rotor **26** and the ring blocks **21** and **30**.

In addition, grooves such as **44** are provided in the face **30***b* of the ring block **30** around the inlet and outlet ports **34** and **36** to receive "O" ring seals **45** for sealing against the closure disk **37**.

The disk **37** has nipples such as **46** extending axially outward from its outer face. These nipples **46** are joined through bores such as **47** with the inlet port **34** as shown and also with the outlet port **35**.

The closure disk **37** is retained in the casing **11** by a snap ring **48** seated in the groove **20** of the casing and extending radially inward from this groove to thrust against the outer face of the disk **37**.

Before the ring block, rotor and closure disk are seated in the casing **11**, a sealing ring **49** composed of graphitic carbon or other material affording a good bearing and sealing surface, is seated in the bore **14** of the end wall **11***a* against the shoulder **17** to present a sealing face extending inward from the bore **14** adjacent the bore **12**.

A drive shaft **50** is provided for driving the rotor **26**. This drive shaft **50** has a splined end portion **50***a* projecting beyond the pilot portion **11***b* to be coupled with a driving motor (not shown). A collar portion **50***b* is provided on the shaft **50** to carry a sealing rib **50***c* on one face thereof to ride on the sealing face **49***a* of the ring **49**. The shaft **50** extends through the hollow hub of the rotor **26** and has an inner splined end **50***d* splined to the splined interior **26***d* of the rotor hub **26***c*. The splined teeth **26***d* extend radially inward into the hollow hub **26***c* to provide abutment shoulders **26***e*.

A coil spring **51** surrounds the shaft **50** in the hollow hub portion of the rotor **26** and is bottomed at its opposite ends on the shoulders **26***e* and collar **50***b*. The spring **51** is effective to urge the shaft **50** toward the end wall **11***a* for holding the rib **50***c* in sealing engagement with the face **49***a* of the ring **49**. Leakage through the bores in the end wall **11***a* in the casing is thereby stopped.

As shown in Figs. 1 and 3, a key **51** is seated in an axial groove **52** in the bore **12** of the casing

11 and projects therefrom into corresponding grooves in the ring blocks **21** and **30** and in the spacer sleeve **29** to hold these members against relative rotative movement to each other and to the casing **11**.

As best shown in Figs. 1 and 6, the groove **24** of the ring block **21** has a plurality of radially extending stator vanes **53** at spaced intervals therearound. These vanes **53** have semi-cylindrical outer edges **53***a* snugly fitting the groove **24** and semi-cylindrical inner edges **53***b* receiving a solid ring **54**. The ring **54** has a flat face **54***a* substantially flush with the face **21***a* of the ring block **21** and with the end portions of the vanes. As shown in Fig. 6, these end portions of the vanes are curved in opposite directions with portions **53***c* disposed in the radially outer part of the groove **24** and arranged to scoop fluid out of the outer ends of the bores **27** of the rotor as the rotor is driven in the counter-clockwise direction shown by the arrows in Figs. 1 and 3. The oppositely inclined portions **53***d* of the vanes **53** are bent or curved to direct fluid into the inner ends of the bores **28** of the rotor. As shown in Fig. 1, the vanes **53** are arranged on the left hand side of the rotor.

The ring block **30** has a plurality of stator vanes **55** in the groove **33** thereof. These vanes extend radially around the groove and have semi-cylindrical outer edges **55***a* snugly fitting the groove wall together with semi-cylindrical inner edges **55***b* receiving a ring **56** similar to the ring **54**. The ring **56** has a flat face **56***a* substantially flush with the face **30***a* of the ring block **30** and flush with the adjacent edges of the vanes **55**.

As shown in Figs. 1 and 5, the vanes have oppositely bent or curved end portions **55***c* and **55***d* with the portion **55***c* lying in the radially outward portion of the groove **33** and arranged to scoop fluid out of the outer ends of the bores **28** and with the portions **55***d* lying in the radially inward portion of the groove **33** and arranged to direct fluid into the inner ends of the bores **27** when the rotor is driven in the counter-clockwise direction indicated by the arrows in Figs. 1 and 3.

The vanes **53** and **55** cooperate with the groove walls in which they are seated and with the rings **54** and **56** which they carry to define a series of radially extending passages or stages in the grooves communicating respectively with the outer ends of one set of inclined bores in the rotor and with the inner ends of the other set of oppositely inclined bores in the rotor. The vanes extend completely around the grooves except where the grooves are blocked off by the partition wall such as **36** shown in Fig. 2. The oppositely bent or offset inner and outer end portions of the vanes are arranged so that fluid which is discharged centrifugally out of the outer ends of the rotor bores is directed into the passages to flow radially inward and be directed into the inner ends of adjacent bores having their outer ends communicating with the radially outer ends of the opposite set of vanes. Fluid thus flows in a somewhat figure 8 path from the passages in one ring block to the passages in the other ring block.

Operation of the pump can be better understood by reference to Fig. 4 which is a phantom view showing the vanes **55** in the ring block **30** and showing the overlying rotor **26**. As illustrated in Fig. 4, fluid from the inlet port **34** is received in the inner end of the first rotor hole **27** and is centrifugally discharged through the outer end of this hole **27** into passages provided by the vanes **53** in the groove **24** (not shown). These

vanes then direct the fluid to the inner end of next adjacent hole 28 of the rotor. Fluid is then centrifugally discharged through the outer end of this hole 28 into the passages provided by the vanes 55 in the groove 33 of the ring block 30. These vanes 55 scoop the fluid out of the outer end of the hole 28 and direct it to the inner end of the next hole 27 which in turn discharges it through its outer end into the passages provided by vanes in the groove 24. These vanes in turn direct the fluid to the inner end of the next hole 28 from which the fluid is centrifugally discharged at the outer end of the hole 28 into passages provided by the vanes 55 in the groove 33. It will be noted that while only about two outer ends of the vanes communicate at any one time with the outer ends of the holes, more than two of the inner ends of the vanes communicate with the inner ends of the holes. This arrangement effects circumferential advancement of fluid in the pumping channel in addition to the advancement provided by rotation of fluid in the holes of the rotor.

After making substantially a complete path around the circumference of the pumping channels, the fluid is discharged out of the outlet port 35 adjacent the barrier 36.

The fluid thus receives a series of centrifugal force impulses each time it is directed into a hole of the rotor. Since adjacent holes of the rotor are inclined in opposite directions, the fluid is picked up first from the right hand side of the rotor, is discharged through the left hand side of the rotor, is directed into the inner ends of the oppositely sloping bores and is centrifugally discharged back through the right hand side of the rotor at a point circumferentially advanced from the inlet port. The fluid traverses through the rotor many times during its course of travel between the inlet and outlet ports and opposite sides of the rotor are under the same fluid pressure so that end thrusts on the bearings 23 and 32 are eliminated.

The vanes 53 separate the right hand pumping channel into a series of radial stages or passageways around the circumference of the channel. The vanes 55 separates the left hand pumping channel into a series of radial passages around the channel. While two separate pumping channels are provided each on opposite sides of the rotor, these channels are connected in series through the bores of the rotor and the fluid flows in a spiral path from one channel through the rotor to the opposite channel and thence back through the rotor to the first channel.

Since leakage from the pumping channels into the hollow interior of the rotor hub may occur, the collar 50b may have its inner face subjected to very high pressures urging the rib 50c too tightly against the seal ring 49. This invention, however, limits the maximum pressure in the hollow hub by venting the hub interior back to a low stage pressure area of the pump through holes 18, 19, and 25. Thus the hub interior can be maintained under any desired maximum pressure by venting into a selected pressure area of a pumping channel. The selected area is preferably adjacent the pump inlet. Any leakage through the vent is thus returned to the pump and the pump seal will not drag or be damaged by excessive pressures.

From the above description it should be understood that this invention now provides a turbine pump with pumping channels on opposite sides of the rotor arranged in series relationship by passages through the rotor and each containing radially extending stator vanes to better separate the pumping channels into distinct stages.

It will, of course, be understood that various details of construction may be varied through a wide range without departing from the principles of this invention and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

We claim as our invention:

1. A pump comprising a rotor with a plurality of spaced alternate oppositely inclined bores defining fluid passages around the circumference thereof, said passages having inner fluid receiving ends and outer discharge ends in radially spaced relationship, vanes adjacent said rotor defining fluid passageways for feeding fluid to the inner ends of said rotor passages and for receiving fluid from the outer ends of said rotor passages, said rotor passages being constructed and arranged to effect a series of incremental pressure increases on fluid as the rotor is rotated relative to the vanes to centrifugally discharge fluid from the outer ends of the rotor passages.

2. A pump comprising a turbine rotor having fluid passages spaced around the periphery thereof with inner fluid receiving ends and outer centrifugal force discharge ends, a pump casing defining a pumping channel adjacent each side of said rotor and communicating with the inner and outer ends of said rotor passages, one of said channels having inlet and outlet ports, a partition in both of said channels separating said ports, and vanes in said channels arranged for directing fluid centrifugally discharged from the outer ends of preceding rotor pasages to the inner ends of succeeding rotor passages whereby rotation of the rotor relative to the vanes will effect a series of pressure enhancing impacts on fluid from the inlet port to discharge the fluid out of the outlet port.

3. In a turbine type pump including a rotor, the improvements of a pumping channel adjacent said rotor, and fluid directing vanes in said pumping channel separating the channel into a plurality of stages.

4. In a turbine type pump including a rotor, the improvements of pumping channels on opposite sides of the rotor and adjacent thereto and fluid directing vanes in said channels separating the channels into a plurality of pumping stages.

5. In a turbine type pump including a rotor, the improvement of a separate pumping channel on each side of the rotor and passages through the rotor connecting the radially inner portion of one channel with the radial outer portion of the other channel.

6. In a pump including a rotor and a pumping channel on each side of the rotor, the improvement of alternate oppositely inclined bores defining fluid flow passages in said rotor connecting the radially inner end of one pumping channel with the radial outer end of the other pumping channel, and fluid flow directing vanes in said channels arranged to receive fluid from the outer ends of the rotor passages and direct fluid into the inner ends of other rotor passages.

7. In a turbine type pump including a rotor having passages with radially inner fluid receiving ends and radially outer fluid discharge ends, said passages being effective to centrifugally discharge fluid received through their inner ends, a pumping channel along side of said rotor, and vanes in said pumping channel arranged for di-

recting fluid to the inner ends of said rotor passages and for receiving fluid from the outer ends of said rotor passages, said vanes being constructed and arranged with oppositely bent inner and outer ends to cause liquids to be drawn into the inner ends of the passages and to scoop liquid out of the outer ends of the passages.

8. A turbine type pump comprising a rotor having opposed faces, annular pumping channels adjacent each opposed face of the rotor, alternate oppositely inclined passages through the rotor connecting the radially inner end of one pumping channel with the radial outer end of the other pumping channel, and fluid directing vanes in said channel separating the channels into a plurality of stages and arranged to scoop liquid out of the outer ends of the rotor passages and feed the liquid to the inner ends of the passages.

9. In a turbine type pump the improvement of means defining an annular pumping channel, radially extending fluid directing vanes at spaced intervals in said channel, and barrier means intermediate the ends of said vanes cooperating with the vanes to direct fluid from the inner ends to the outer ends of the vanes.

10. A high pressure developing low delivery rate turbine pump which comprises means defining opposed annular pumping channels, radially extending vanes in said channels arranged to advance fluid around the channels, a rotor between said channels, and passages in said rotor connecting said channels in series whereby rotation of the rotor will effect incremental pressure boosts on the liquid and liquid will flow through the passages and between the vanes in a figure eight path around said pumping channels.

11. A turbine pump comprising a casing having a bore extending inwardly from one end thereof to an end wall, said end wall of the casing having an axial bore therethrough, opposed ring blocks in said bore of the casing having central apertures aligned with the aperture of said end wall of the casing, annular grooves in the opposed faces of said ring blocks, said annular grooves having semicircular cross sections, bearings in the apertures of said ring blocks, a sleeve in said bore of the casing separating the grooved faces of said ring blocks, a rotor having an aperture therethrough, a disk portion between said ring blocks and hollow hubs rotatably mounted in said bearings, said disk portion of the rotor having alternate oppositely inclined bores therethrough joining the radially inner end of one groove with the radially outer end of the other groove, radially extending fluid flow directing vanes in said grooves of the ring blocks, ring members carried by said vanes on their inner edges intermediate the radially inner and outer end portions thereof, a closure plate in said bore of the casing, means venting the groove of the ring block adjacent said closure plate to the space between said ring block and closure plate to pressure the ring block against the sleeve, said closure plate and said adjacent ring block having aligned inlet and outlet ports, the inlet port of said ring block opening into the radially inner portion of the annular groove in said ring block, the outlet port of said ring block opening into the radially outer portion of said annular groove, a partition wall

extending across the grooves of said ring blocks between the inlet and outlet ports, a drive shaft extending through the aperture in said end wall of the casing and into the aperture of said rotor, means connecting said drive shaft with said rotor, seal means on said drive shaft, cooperating seal means carried in the aperture of said end wall of the casing, a spring urging the seal means of the drive shaft against the cooperating seal means carried by the end wall of the casing, and means providing a passage connecting the hollow interior of said rotor with a groove in one of said ring blocks to vent the interior of the rotor to a low pressure area of the pump.

12. A turbine type pump comprising a rotor, a separate annular pumping channel on each side of said rotor, an inlet port in one of said channels, an outlet port in said one channel, a barrier wall separating the inlet and outlet ports, said channels having a plurality of flow paths with outer inlet ends and inner outlet ends and fluid flow passages through said rotor having alternately arranged oppositely inclined paths connecting the radially inner ends of the flow paths in one channel with the radially outer ends of the flow paths in the other channel for directing fluid in criss-cross relation between the channels to advance through the flow paths in the channels to effect a series of incremental pressure boosts on liquid introduced through the inlet port and to discharge the liquid under high pressures out of the outlet port.

13. In a pump a rotor having a hollow hub, a casing defining a pumping channel, a drive shaft extending into the hollow hub of the rotor, coacting seal means respectively carried by the drive shaft and the pump casing, and means venting the hollow hub of the rotor back to a low pressure stage of the pump to limit pressure on the seal means to a predetermined pressure.

14. In a turbine type pump a rotor having a hollow internally splined hub, a casing defining opposed pumping channels rotatably supporting the hollow hub of said rotor, a drive shaft extending into said casing having a splined end coupled to the splined portion of the hollow hub of the rotor, coacting seal means carried by the pump casing and the drive shaft for sealing the hollow hub of the rotor, and means providing passageways connecting the hollow hub of the rotor with a low pressure stage of a pumping channel to limit pressure exerted on the cooperating sealing means.

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