May 12, 1964 C. D. BOWER 3,132,595

AXIAL FLOW PUMP

Filed Oct. 30, 1961 4 Sheets-Sheet 1

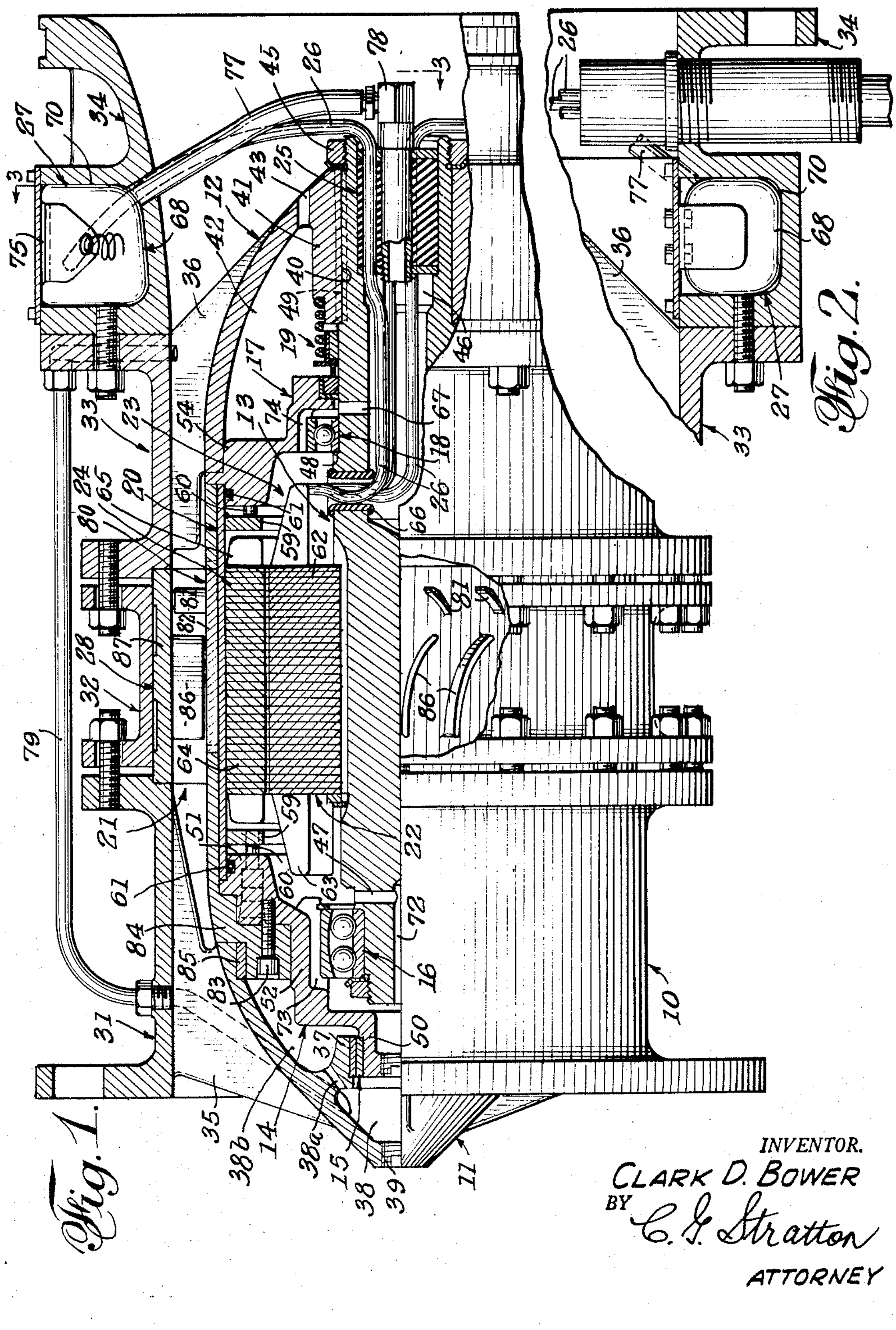
Fig. 1.

Fig. 2.

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AXIAL FLOW PUMP

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Fig. 5.

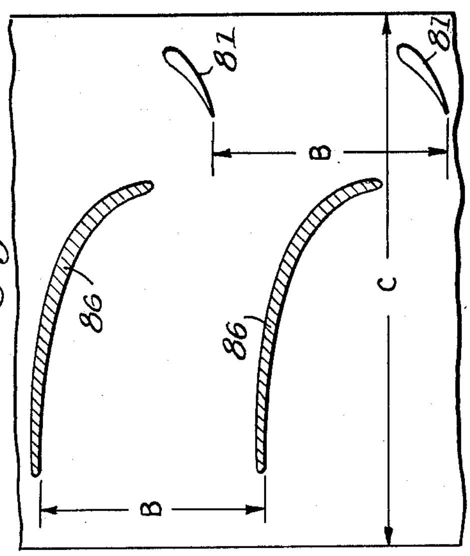


Fig. 6.

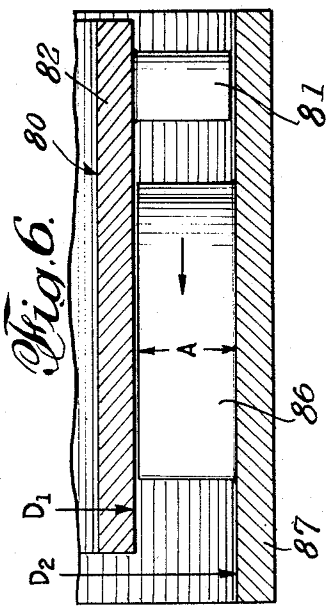


Fig. 3.

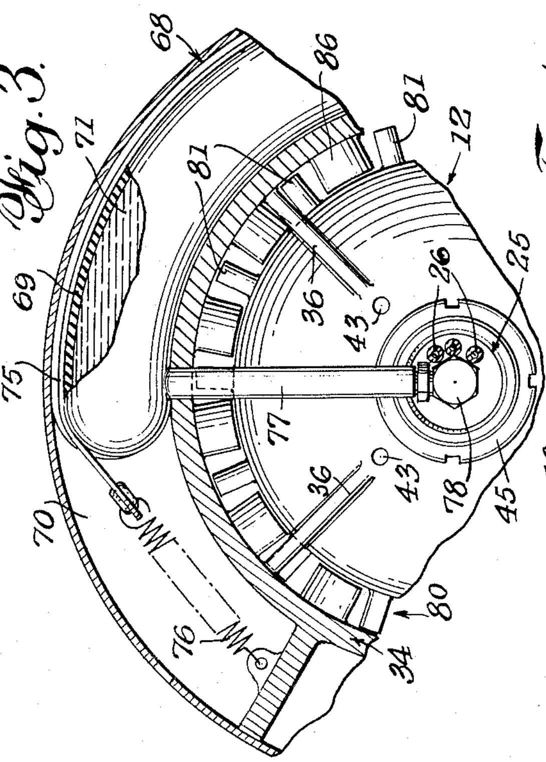
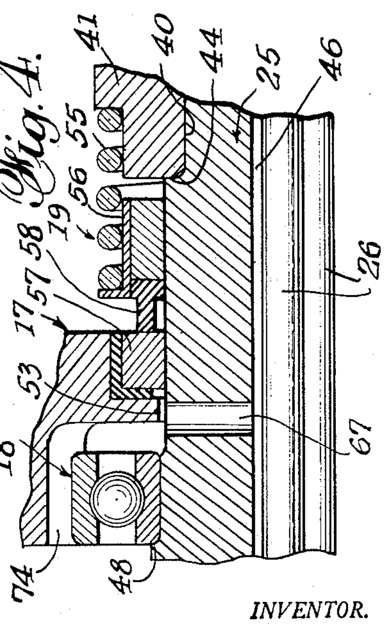


Fig. 4.



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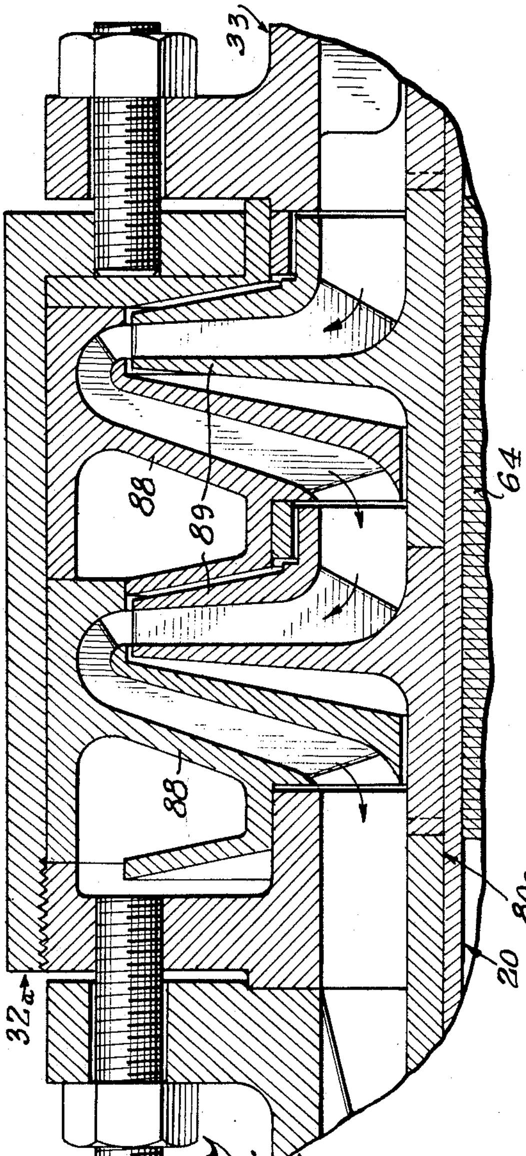

Fig. 7.

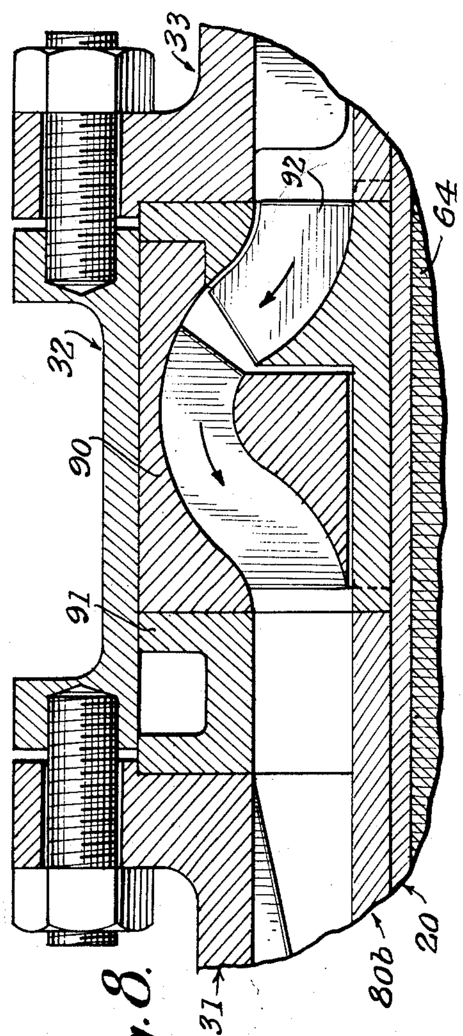

Fig. 8.

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Fig. 10.

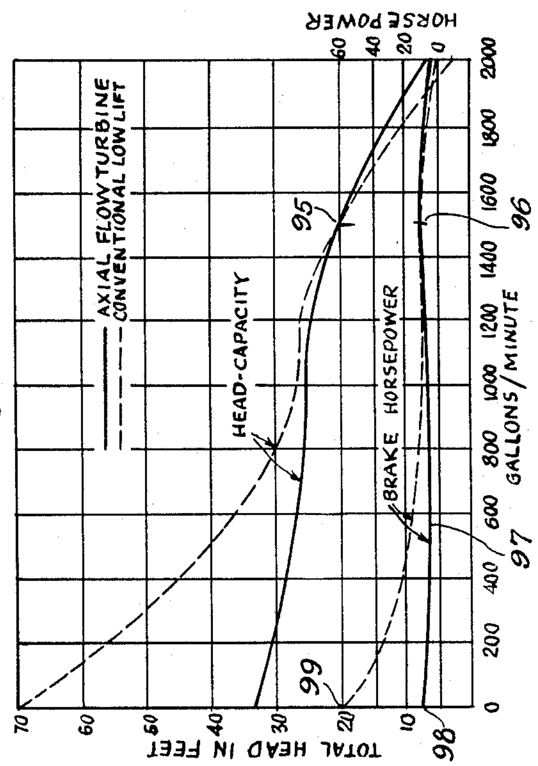
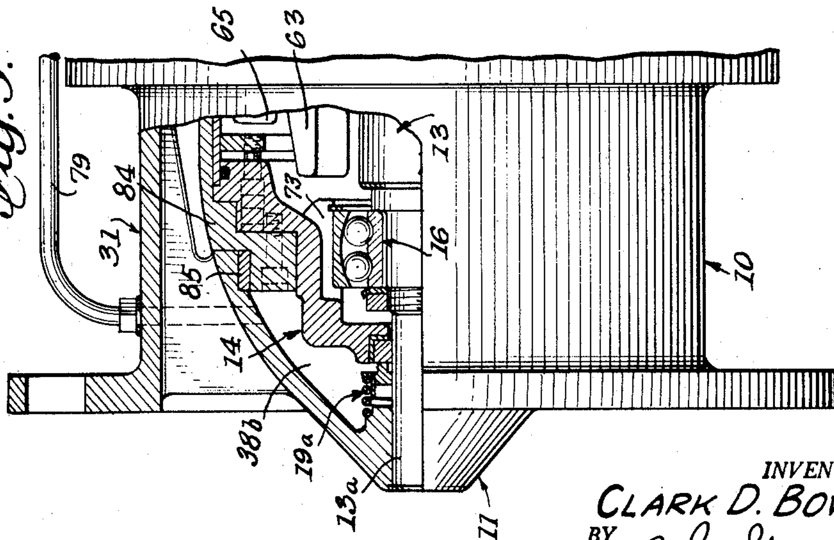


Fig. 9.



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3,132,595
AXIAL FLOW PUMP

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Filed Oct. 30, 1961, Ser. No. 148,620
16 Claims. (Cl. 103—87)

This invention relates to a unitary device that comprises an axial flow pump and an inverted drive motor therefor.

An object of the present invention is to provide a combination pump and inverted motor such that each may be increased in length with the pump developing the desired head and the motor designed to develop the horsepower required to drive such a lengthened pump. Such lengthened units are ordinarily required to operate at a rotative speed greater than the first critical speed. Since, on acceleration through the first critical speed, vibration may be encountered in lengthened motor-pump units as contemplated, the invention has for another object to provide means to stabilize such vibration not only when the unit passes through its first critical speed but also at each succeeding critical speed as full rotative speed is obtained.

Another object of the invention is to provide, in such an assembly, hydraulic pressure balance on the motor to balance the pressure differential between the discharge and suction ends of the pump as imposed on the motor.

A still further object of the invention is to provide a combined unit, as above, in which the motor is submersible and is inverted. Thus, the outside of the motor rotates and the construction entails the use of anti-friction bearings that permit reverse rotation and reversal of thrust.

A yet further object of the invention is to provide a motor-pump unitary assembly of the character above referred to in which provision is made for circulating lubrication through and around the motor in copious quantities that assure continuous supply of lubricant to the bearings previously mentioned.

Another object of the invention is to provide a unitary assembly as above in which the pump vanes are so mounted as to render multi-staging easy, thereby enabling proportioning the numbers of diffusion and impeller vanes of the pump, as desired. Thus, the hydraulic characteristics of the pump may be accurately controlled and/or determined.

A still further object of the invention is to provide a combined motor and pump construction in which the pump design and characteristic may be varied by providing for interchangeability of the vane structure and arrangement. Therefore, based on the present combined device, the characteristics, number, size, proportion and disposition of the pump vanes, as well as providing single- or multi-stage design, may be had, as desired.

A further object of the invention is to provide an axial flow pump embodying a particular relationship and control in the dimensions of the above-mentioned pump vane characteristics, whereby shut-off horsepower is lower than the horsepower at maximum efficiency and is also lower than the shut-off power of conventional low-lift pumps of comparable head capacity at the same maximum efficiency.

A yet further object of the invention is to provide a motor-pump structure in which the motor is lubricated by pressure fluid and the same is isolated from the fluid passing through the pump.

A further object of the invention is to provide a structure, as above, in which, notwithstanding head and expansion of the fluid being pumped, the motor lubricant is maintained at a higher pressure than the pressure of the pump fluid, thereby insuring against ingress, for any reason whatever, of such pump fluid into the internal structure of the motor.

This invention also has for its objects to provide such means that are positive in operation, convenient in use, easily installed in a working position and easily disconnected therefrom, economical of manufacture, relatively simple, and of general superiority and serviceability.

The invention also comprises novel details of construction and novel combinations and arrangements of parts, which will more fully appear in the course of the following description and which is based on the accompanying drawings. However, said drawings merely show, and the following description merely describes, preferred embodiments of the present invention, which are given by way of illustration or example only.

In the drawings, like reference characters designate similar parts in the several views.

FIG. 1 is a partly broken side elevational view, in quarter section, of an axial flow pump combined with an interiorly located operating motor according to the present invention.

FIG. 2 is a fragmentary sectional view of a modification.

FIG. 3 is a fragmentary cross- sectional view as taken on the line 3—3 of FIG. 1.

FIG. 4 is an enlarged and detailed view showing a pressure-sealing feature of the invention.

FIG. 5, to the same scale, is a semi-schematic view of a form of pump vane arrangement, as used in the invention.

FIG. 6 is a longitudinal sectional view thereof.

FIG. 7 is a similarly enlarged and fragmentary sectional view of another form of pump vane arrangement.

FIG. 8 is a similar view of still another pump vane arrangement.

FIG. 9 is a quarter-sectioned elevational view of the discharge end of the present motor-pump unit and showing a modification.

FIG. 10 is a graph showing comparative performance curves between a unit according to the present invention and a conventional low-lift pump.

The present combined pump and motor structure comprises, generally, a sectional outer, tubular housing **10**, an end bearing cap **11** coaxial with said housing and in fixed relationship thereto, an end bearing cap **12** opposite to the cap **11** and coaxial therewith, a fixed axle **13** on the axis of said caps and fixedly carried by the cap **12** and extending in a direction toward the bearing cap **11**, a cap plate **14** rotationally carried by the cap **11**, a vibration-stabilizing bearing **15** in cap **11** for said cap plate **14**, an anti-friction bearing **16** between said cap plate and the free end of the fixed axle **13**, a second cap plate **17**, opposed to the cap plate **14**, rotationally carried by the fixed axle, an anti-friction bearing **18** between the axle and the cap plate **17**, pressure-sealing means **19** between the latter cap plate and the cap **12** to balance against pressure between said cap plates **14** and **17**, a tubular wall **20** that spans between said cap plates and defining an annular passage **21** between said wall and the housing **10**, a stator **22** of a squirrel cage motor carried by the axle **13** in the interior space **23** within said wall **20**, a motor rotor **24** electrically associated with the stator **22** and carried on the inner face of the wall **20**, a sealing plug **25** at one end of the axle and through which fluid to lubricate the bearings **16** and **18** is conducted to the interior space **23** and which seals around electrical conductors **26** to the motor stator to produce a potential therein that, by induction, energizes the rotor **24**, means **27** to supply lubricating fluid to space **23** at a pressure different and preferably greater than the pressure head on the pump, and pump means **28** in said annulus **21** carried, in part, by the housing **10** and, in part, by the tubular wall **20**.

The housing **10** is shown as comprising a discharge end section **31**, a pump section **32** connected by bolts to the inner end of section **31**, an intermediate section **33** similarly connected to section **32**, and an inlet end section **34** connected to the section **33**. As can be seen in FIG. 1, the housing section **31** is integrally connected to the end cap **11** by webs **35**. Similar webs **36** integrally connect the section **33** with the end cap **12**. It is common practice to provide sections **31** and **34** with flanges or other portions for connection of the housing in operative position.

The caps **11** and **12** are preferably conical, as shown, thereby providing the annulus **21** with enlarged inlet and discharge throats, as appear in FIG. 1, the same providing for a smooth and gradual change in flow velocity through passage **21**.

In the preferred form of FIG. 1, the cap **11** is shown with an interior bearing boss **37** that defines a chamber **38** in the nose of the cap which is closed by an end plug **39**. The larger inner, circular end of cap **11** is formed with an annular bearing face. Said chamber **38**, by means of a passage **38*a*** in the bearing boss **37**, has communication with an inner chamber **38*b*** that is enclosed between the wall of cap **11** and the cap plate **14**.

The cap **12**, at its smaller outer end, has an axial bore **40** that is formed within an axial hub **41** that extends toward but short of the larger inner end of said cap. The inner space **42** defined by the cap **12** is open to the outside by means of holes **43**.

The axle **13** is shown as a shaft that is fitted into bore **40**, the same having a shoulder **44** that abuts the end of the hub **41** and is secured in place in the cap **12** by means of a nut **45**. Said axle is formed with a bore **46** that is open at the inlet end of the structure. An annular shoulder **47** on said axle locates the bearing **16** on the discharge end of the axle, and a shoulder **48** on said axle locates the bearing **18**, said shoulders **47** and **48** being opposed, as shown. A key **49** fixedly connects said axle and the cap **12**.

The cap plate **14** is disposed inwardly of the cap **11** and has a hub **50** that is coaxial with the axle **13** beyond the free end thereof. The vibration-stabilizing bearing **15**, shown as a sleeve-bushing bearing, is carried by the bearing boss **37** of the cap **11** and engages over said hub **50**. It will be clear that said bearing **15** dampens or stabilizes any tendency of the cap plate **14** to vibrate on the axis thereof. Said cap plate **14** is formed with a peripheral or outer annular portion **51** that extends inward from the hub **50**, the same having an intermediate portion **52** that houses the anti-friction bearing **16**.

Said bearing **16** non-frictionally connects said axle **13** and the cap plate **14**. The same is shown as a double-race bearing with its inner race mounted on the axle and its outer race fitted, as above explained, in the portion **52** of the cap plate **14**. Since said cap plate is steadied by the cap **11**, due to bearing **15**, the outboard end of the axle **13** is steadied by bearing **16** while the cap plate **14** is freely rotational around the axis of said axle.

The modification of FIG. 9 omits the bearing **15** between the cap **11** and the cap plate **14**, but extends the axle, as at **13*a***, to have bearing directly in the cap **11**.

The cap plate **17** is disposed inward of the end cap **12** and has a central opening **53** through which the axle **13** extends. The outer peripheral portion **54** of said cap plate is fitted into the inner end of cap **12**. The anti-friction bearing **18** provides for a rotational fit of the plate **17** on the axle.

The pressure-sealing means **19**, shown in detail in FIG. 4, comprises an expansion spring **55** that abuts the inner end of the cap hub **41**, a follower ring **56** around the axle **13** and biased by said spring **55** inwardly toward the cap plate **17**, an abutment ring **57** in said cap plate, and a pressure ring **58** interposed between the follower **56** and the ring **57** and transmitting the pressure of spring **55** to the plate **17** through the ring **57**. As will later be clear, the internal pressure between cap plates **14** and **17** and within wall **20** is greater, during operation, than is the outside pressure. Thus, the means **19** seals the chamber **42** from flow into chamber **23** so that pressure therein is effective against the cap plate **17**, said pressure being the pressure at the inlet end of the flow through the pump.

The modification of FIG. 9 shows a similar pressure-sealing means **19*a***, the same sealing chamber **38*b*** so the pressure therein is effective against the cap plate **14** and is opposed to the pressure in chamber **42**.

The tubular wall **20** spans between the peripheral portion **51** of the cap plate **14** and the peripheral portion **54** of the cap plate **17**. Flange rings **59** welded to wall **20** and inward of the respective portions **51** and **54**, are connected to said portions by cap screws **60**, thereby fixedly connecting said wall **20** to the cap plates **14** and **17** to define the mentioned interior space **23**. O-rings **61** seal between said wall **20** and the outer annular surfaces of the cap plates. Thus, the mentioned annular passage **21** separates the fixed outer housing **10** and the rotationally-mounted assembly of cap plates **14** and **17** and cylindrical wall **20**.

The motor stator **22** is generally typical of squirrel cage or similar induction motors and is here shown with a laminated-magnet stack **62** that is fixedly carried by the axle **13** with the usual induction windings **63**. Said stack and windings are disposed between the cap plates **14** and **17**.

The motor rotor **24** is shown with a laminated-magnet stack **64** affixed to the inside of wall **20** and having secondary windings **65**, said rotor, in this case, being disposed between the flange rings **59** and, of course, electrically aligned with the stator **22**.

The sealing plug **25** is shown as a non-metallic element that is fitted tightly into the bore **46** of the axle. Since the bore **46** is open to the interior space **23** through a conductor-passing grommet **66** in the axle **13** and said axle is provided with one or more ports **67** in the vicinity of the bearing **18** so that lubrication fluid in space **23** may circulate freely around said bearing, said plug serves to effectively seal against ingress into the motor of fluid from the outside. It will be clear that the pressure-sealing means **19** also seals in said internal fluid against leakage to the space **42** which is open to outside fluid entry through holes **43**.

The electrical conductors **26** pass longitudinally through said plug **25** to windings **63**, the plug sealing around said conductors so that the latter may be brought to the motor while the latter is submersed in the medium in which the pump is operating.

The means **27** is provided because it is desirable that the fluid within the space **23** around the motor be a different fluid than the fluid circulating through the annular passage **21** and also have a higher pressure than the fluid being pumped, notwithstanding heat and expansion. To this end, the means **27** is shown as comprising an expansion chamber **68** that is external of the motor and is located so as to be exposed or subject to the pressure of the fluid being pumped. Said chamber is disclosed as an elastic container **69** that is housed in a seat **70** provided in the section **34** of the housing **10**. In FIG. 1, said seat is shown in a device for wet pit installation, and in FIG. 2, in a device for dry pit or pipe-line installation. The circumferential extent of the sausage-like container **69** may vary depending on the fluid capacity desired. Said expansion chamber is exposed to the fluid being pumped on its external surface and, interiorly, the same contains fluid **71** that is supplied to the space **23** around the motor and circulating around the bearings **16** and **18**, around the former because of passage **72** in the axle **13** and passage **73** in the cap plate **14**, and around the latter because of the mentioned ports **67** in the axle and passage **74** in the cap plate **17**.

Said means **27** provides for placing pressure on the fluid **71**. To this end, a band **75**, placed in tension by a spring or comparable means **76**, compresses the outside of the container **69**. The bias of spring **76** may be set as desired and in relation to the pressure at the inlet end of the pump, irrespective of the type of installation used. A tube **77** extends from the container **69** and connects to a tubular fitting **78** that extends through sealing element **25** and discharges into the bore **46** of the axle from which fluid from container **69** enters space **23** through the grommet **66** and the ports **67**.

It will be noted that the means **27** is integrated with the present pump-motor unit so that facility of handling and connection of the parts is had.

By conducting inlet pressure of the pump, by means of a pipe **79**, to chamber **38b** by way of chamber **38** and passage **38a** of FIG. 1, or directly to chamber **38b** of FIG. 9, the opposite ends of the rotor, i.e., the cap plates **14** and **17**, are subject to the substantially equal and opposite pressure of chambers **38b** and **42**.

Three different forms of pump means **28** are shown. In the form shown in FIGS. 1, 5 and 6, said means comprises a propeller **80** carried by the motor rotor and comprising a set of vanes **81** extending radially outward from a ring or rings **82** that are adapted to be longitudinally stacked on the rotor wall **20** and held in place by cap screws **83** that connect a thickened annular portion **84** of one of said rings **82** to the outer portion **51** of the cap plate **14**. A sealing ring **85** seals against differential hydraulic pressure between the discharge end of the pump and the motor. In this case, said ring is interposed between the large end of the cap **11** and the portion **84** of the end impeller ring **82**.

The number, dimensions, proportions and placement of the stationary vanes **86** that cooperate with the rotating vanes **81** and which extend radially inward from a fixed sleeve **87** fitted in pump section **32** of the housing **10** provide characteristics that are advantageous and produce efficient pumping operation.

The vanes **86** are disposed on the discharge side of the vanes **81** and receive the discharge of the latter vanes on their concave faces for expression in an outward direction toward the left, as in FIGS. 1, 5 and 6.

Where

A=Width of stationary vanes
B=Vane spacing B
C=Length of stage
D_1=Hub diameter
D_2=Vane outer diameter
P=Pitch in inches

$$\frac{A}{B}=0.4 \text{ to } 1.0$$

$$\frac{A}{C}=0.25 \text{ to } 0.5$$

$$\frac{D_1}{D_2}=0.65 \text{ to } 0.85$$

The foregoing, while exemplary, is preferred, as is a propeller pitch ratio of 8 to 22 for a 10-inch axial flow pump. Also, the ratio of

$$\frac{P}{D_2}=.89 \text{ to } 2.45$$

is preferred.

Referring to the chart, FIG. 10, an axial flow turbine which has the number, dimensions, and placement of the vanes as above set forth and for a capacity of 1500 gallons per minute as shown at point **95**, will operate at peak or maximum horsepower of about ten, as indicated at point **96**. It will be noted from the horsepower line **97** that the brake horsepower lowers as flow decreases, dropping to nine horsepower at zero discharge or shut-off as indicated at **98**. When this performance is compared to the performance of a conventional low-lift pump of the same flow capacity at the same maximum horsepower, the horsepower at shut-off rises to sixty, as indicated at **99**. Pump life, uniformity of performance, and a general improvement in operating efficiency, follow from such design and arrangement changes over conventional low-lift pumps.

The present pump may be designed as a single- or multi-stage centrifugal type pump, as in FIG. 7, the pump stator **32a** replacing the housing section **32** and mounting one or more stationary bowl units **88**, and the pump rotor **80a** being provided with one or more cooperating impellers **89**. The latter produce a centrifugal force on the fluid being pumped and are expressed in a discharge direction by the stationary units **88**.

A mixed flow may be provided, as in FIG. 8, wherein the housing section **32** mounts a fixed bowl **90**, a spacer **91**, if needed, fixing said bowl in place, and the rotor **80b** being provided with a cooperating impeller **92**. The mixed flow is caused by designing said bowl and impeller to give both longitudinal and centrifugal force to the fluid being moved by the pump.

While the foregoing has illustrated and described what is now contemplated to be the best mode of carrying out the invention, the constructions are, of course, subject to modification without departing from the spirit and scope of the invention. Therefore, it is not desired to restrict the invention to the particular forms of construction illustrated and described, but to cover all modifications that may fall within the scope of the appended claims.

Having thus described this invention, what is claimed and desired to be secured by Letters Patent is:

1. A pump comprising a fixed tubular housing, two hollow, longitudinally spaced end caps within and rigidly connected to said housing, one at the inlet and the other at the outlet end of the pump, a fixed axle extending from one cap toward the other, an induction motor stator fixedly carried by said axle between said caps, a tubular wall coaxial with said axle and disposed between said caps, a pair of cap plates on opposite sides of the stator closing the ends of said tubular wall and respectively closing the hollows of the caps, a rotational bearing between one cap and the cap plate at that end, an anti-friction bearing between the latter cap plate and the axle, an anti-friction bearing between the other cap plate and the axle, means rigidly connecting said tubular wall and the cap plates to form a stator-enclosing assembly rotational on the axle and having an interior space, a motor rotor carried by said tubular wall in electrical relationship to the mentioned stator, an annular passage being defined between the tubular housing and the tubular wall, and cooperating pump components disposed in said passage, one carried by the rotational tubular wall and the other by the fixed tubular pump housing, the hollows of both caps being vented to the inlet end of the pump to provide equal and opposite pressure in said hollows against the cap closure plates to balance the pressure differential between the discharge and suction ends of the pump as imposed on the motor rotor.

2. A pump according to claim 1 in which the axle is provided with an extension beyond the first-mentioned anti-friction bearing, and a bearing for said extension is provided in the first-mentioned cap.

3. A pump comprising a fixed tubular housing, two hollow, longitudinally spaced end caps within and rigidly connected to said housing, one at the inlet and the other at the outlet end of the pump, a fixed axle extending from one cap toward the other, an induction motor stator fixedly carried by said axle between said caps, a tubular wall coaxial with said axle and disposed between said caps, a pair of cap plates on opposite sides of the stator closing the ends of said tubular wall and respectively closing the hollows of the caps, a rotational bearing between one cap and the cap plate at that end, an anti-friction bearing between the latter cap plate and the axle, an anti-friction bearing between the other cap plate and the axle, means rigidly connecting said tubular wall and the cap plates to form a stator-enclosing assembly rotational on the axle and having an interior space, a motor rotor carried by said tubular wall in electrical relationship to

the mentioned stator, the hollows of both caps being vented to the inlet end of the pump to provide equal and opposite pressure in said hollows against the cap closure plates to balance the pressure differential between the discharge and suction ends of the pump as imposed on the motor rotor means to conduct lubrication fluid into said interior space, means to place said fluid under pressure, a shoulder on said axle, means to resiliently bias the stator-enclosing assembly against said shoulder, an annular passage being defined between the tubular housing and the tubular wall, and cooperating pump components disposed in said passage, one carried by the rotational tubular wall and the other by the fixed tubular pump housing.

4. A pump according to claim 3 in which the axle is provided with an extension beyond the first-mentioned anti-friction bearing, and a bearing for said extension is provided in the first-mentioned cap.

5. A pump comprising a fixed tubular housing, two hollow, longitudinally spaced end caps within and rigidly connected to said housing, one at the inlet and the other at the outlet end of the pump, a fixed axle extending from one cap toward the other, an induction motor stator fixedly carried by said axle between said caps, a tubular wall coaxial with said axle and disposed between said caps, a pair of cap plates on opposite sides of the stator closing the ends of said tubular wall and respectively closing the hollows of the caps, a rotational bearing between one cap and the cap plate at that end, an anti-friction bearing between the latter cap plate and the axle, an anti-friction bearing between the other cap plate and the axle, means rigidly connecting said tubular wall and the cap plates to form a stator-enclosing assembly rotational on the axle and having an interior space, a motor rotor carried by said tubular wall in electrical relationship to the mentioned stator, the hollows of both caps being vented to the inlet end of the pump to provide equal and opposite pressure in said hollows against the cap closure plates to balance the pressure differential between the discharge and suction ends of the pump as imposed on the motor rotor means to conduct lubrication fluid into said interior space, means to place said fluid under pressure, a shoulder on said axle, means to resiliently bias the stator-enclosing assembly against said shoulder, passage and port means in said axle to conduct said lubrication to said interior space and around the anti-friction bearings to lubricate the latter, an annular passage being defined between the tubular housing and the tubular wall, and cooperating pump components disposed in said passage, one carried by the rotational tubular wall and the other by the fixed tubular pump housing.

6. A pump comprising a fixed tubular housing, two hollow, longitudinally spaced end caps within and rigidly connected to said housing, one at the inlet and the other at the outlet end of the pump, a fixed axle extending from one cap toward the other, an induction motor stator fixedly carried by said axle between said caps, a tubular wall coaxial with said axle and disposed between said caps, a pair of cap plates on opposite sides of the stator closing the ends of said tubular wall and respectively closing the hollows of the caps, a rotational bearing between one cap and the cap plate at that end, an anti-friction bearing between the latter cap plate and the axle, an anti-friction bearing between the other cap plate and the axle, means rigidly connecting said tubular wall and the cap plates to form a stator-enclosing assembly rotational on the axle and having an interior space, a motor rotor carried by said tubular wall in electrical relationship to the mentioned stator, the hollows of both caps being vented to the inlet end of the pump to provide equal and opposite pressure in said hollows against the cap closure plates to balance the pressure differential between the discharge and suction ends of the pump as imposed on the motor rotor, said axle having an end bore with ports and passages extending from said bore into said interior space, a compressible plug closing said bore, means extending through said plug to conduct fluid under pressure through said bore, ports and passages, an annular passage being defined between the tubular housing and the tubular wall, and cooperating pump components disposed in said passage, one carried by the rotational tubular wall and the other by the fixed tubular pump housing.

7. A pump according to claim 6 provided with electrical coductors to supply current to the stator, said conductors extending longitudinally through said plug and tightly sealed therein.

8. In a pump, a fixed tubular housing, a multi-stage pump component fixedly carried within the housing, a pair of oppositely arranged coaxial and hollow caps within said housing, one at the inlet and the other at the outlet end of the pump, with an annular passage therebetween, a fixed axle carried by one cap and extending coaxially toward the other cap, a motor stator between the caps and fixed on the axle, an enclosed motor housing rotationally mounted on the axle and enclosing the motor stator, said motor housing having an outer tubular wall, a motor rotor carried by said wall in electrical association with the stator and provided with end plates in hollow-enclosing engagement with the hollow caps, the hollows of said caps being vented to the inlet of the pump to hydraulically balance the thrust, on opposite ends, on the motor housing, and a second multi-stage pump component carried by said wall and operatively associated with the mentioned multi-stage fixed component, the length of the tubular wall and of the motor being proportional to the length of the operatively associated pump components.

9. In a pump according to claim 8, means to supply lubrication fluid to said motor housing, and means mounted on the fixed housing to place said fluid under pressure greater than the suction pressure of the fluid being pumped between the pump components.

10. In a pump according to claim 8, said axle having fluid passages therein to conduct said fluid to the motor housing, a plug closing the end of said axle passages, and a connection between the means to place the fluid under pressure and extending longitudinally through said plug into communication therebeyond with the mentioned fluid passages.

11. In a pump, a fixed tubular housing, a pump component fixedly carried within the housing, a pair of oppositely arranged coaxial and hollow caps within said housing, one at the inlet and the other at the outlet end of the pump, with an annular passage therebetween, a fixed axle extending between and having its ends in bearing engagement with said caps, a motor stator between the caps and fixed on the axle, an enclosed motor housing rotationally mounted on the axle and enclosing the motor stator, said motor housing having an outer tubular wall, a motor rotor carried by said wall in electrical association with the stator and provided with end plates in hollow-enclosing engagement with the hollow caps, the hollows of said caps being vented to the inlet of the pump to hydraulically balance the thrust, on opposite ends, on the motor housing, and a second pump component carried by said wall and operatively associated with the mentioned fixed component.

12. In a pump, a fixed tubular housing, a pump component fixedly carried within the housing, a pair of oppositely arranged coaxial and hollow caps within said housing, one at the inlet and the other at the outlet end of the pump, with an annular passage therebetween, a fixed axle carried by one cap and extending coaxially toward the other, a motor stator between the caps and fixed on the axle, an enclosed motor housing rotationally mounted on the axle and enclosing the motor stator, said motor housing having an outer tubular wall, a motor rotor carried by said wall in electrical association with the stator and provided with end plates in hollow-enclosing engagement with the hollow caps, the hollows of

said caps being vented to the inlet of the pump to hydraulically balance the thrust, on opposite ends, on the motor housing, and a second pump component carried by said wall and operatively associated by the mentioned fixed component, the fixed pump component comprising an annular sleeve having an internal diameter D_2 and provided with radial and inwardly directed vanes on circumferential spacing B and having a width A, the rotational pump component comprising a ring having an external diameter D_1 and a length C, said diameters, vane spacing, vane width and ring length being proportionally related substantially as follows:

$$\frac{A}{B}=0.4 \text{ to } 1.0$$

$$\frac{A}{C}=0.25 \text{ to } 0.5$$

$$\frac{D_1}{D_2}=0.65 \text{ to } 0.85$$

said proportionally related internal and external diameters, circumferential spacing, vane width, and ring length providing a pump having a shut-off brake horsepower lower than the peak horsepower of the pump.

13. In pump, a fixed tubular housing, a pump component fixedly carried within the housing, a pair of oppositely arranged coaxial and hollow caps within said housing, one at the inlet and the other at the outlet end of the pump, with an annular passage therebetween, a fixed axle carried by one cap and extending coaxially toward the other, a motor stator between the caps and fixed on the axle, an enclosed motor housing rotationally mounted on the axle and enclosing the motor stator, said motor housing having an outer tubular wall, a motor rotor carried by said wall in electrical association with the stator and provided with end plates in hollow-enclosing engagement with the hollow caps, the hollows of said caps being vented to the inlet of the pump to hydraulically balance the thrust, on opposite ends, on the motor housing, and a second pump component carried by said wall and operatively associated by the mentioned fixed component, the fixed pump component comprising an annular sleeve having an internal diameter D_2 and provided with radial and inwardly directed vanes on circumferential spacing B and having a width A, the rotational pump component comprising a ring having an external diameter D_1 and a length C, said diameters, vane spacing, vane width and ring length being proportionally related substantially as follows:

$$\frac{A}{B}=0.4 \text{ to } 1.0$$

$$\frac{A}{C}=0.25 \text{ to } 0.5$$

$$\frac{D_1}{D_2}=0.65 \text{ to } 0.85$$

and the pitch of the propellers being the range between eight (8) and twenty-two (22) per circumference, and

$$\frac{P}{D_2}=.89 \text{ to } 2.45$$

said proportionally related internal and external diameters, circumferential spacing, vane width, and ring length providing a pump having a shut-off brake horsepower lower than the peak horsepower of the pump.

14. In a pump, a fixed tubular housing, a pump component fixedly carried within the housing, a pair of oppositely arranged coaxial and hollow caps within said housing, one at the inlet and the other at the outlet end of the pump, with an annular passage therebetween, a fixed axle carried by one cap and extending coaxially toward the other cap, a motor stator between the caps and fixed on the axle, an enclosed motor housing rotationally mounted on the axle and enclosing the motor stator, said motor housing having an outer tubular wall, a motor rotor carried by said wall in electrical association with the stator, a second pump component carried by said wall and operatively associated by the mentioned fixed component, an opening in the cap at the inlet end of the pump to admit inlet pressure to the interior of said cap, means to conduct such inlet pressure around the motor housing and into the interior of the other cap, the pressures in said cap interiors being equal and opposite and thereby hydraulically balancing the thrust, from opposite ends, on the motor housing.

15. In a pump, a fixed tubular housing, a pump component fixedly carried within the housing, a pair of oppositely arranged coaxial and hollow caps within said housing, one at the inlet and the other at the outlet end of the pump, with an annular passage therebetween, a fixed axle carried by one cap and extending coaxially toward the other cap, a motor stator between the caps and fixed on the axle, an enclosed motor housing rotationally mounted on the axle and enclosing the motor stator, said motor housing having an outer tubular wall, a motor rotor carried by said wall in electrical association with the stator, a second pump component carried by said wall and operatively associated by the mentioned fixed component, an opening in the cap at the inlet end of the pump to admit inlet pressure to the interior of said cap, means to conduct such inlet pressure around the motor housing and into the interior of the other cap, the pressures in said cap interiors being equal and opposite and thereby hydraulically balancing the thrust, from opposite ends, on the motor housing the fixedly carried pump component comprising a multi-stage unit having at least two side-by-side interiorly-open bowl units and an enclosure for said units having a circumferential wall, said unit being interposed between the inlet and outlet ends of said housing and fixedly connecting said ends, and the second pump component comprising a multi-stage set of impellers in operative association with the mentioned bowls.

16. A pump comprising a tubular housing provided with two fixed longitudinally spaced hollow caps, one at the inlet and the other at the outlet end of the housing, a motor stator carried by one cap and disposed in the space therebetween, a motor rotor around the stator and having ends closing the hollows of the caps, the inlet and outlet of the pump being connected by a tubular passage defined between the housing on the outside and the caps and motor rotor on the inside, cooperating pump components extending into said passage from said housing and motor rotor, an opening in the cap at the inlet end of the pump to admit inlet pressure to the interior of said cap, means to conduct such inlet pressure around the motor housing and into the interior of the other cap, the pressures in said cap interiors being equal and opposite and thereby hydraulically balancing the thrust, from opposite ends, on the motor housing.

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