

April 27, 1965

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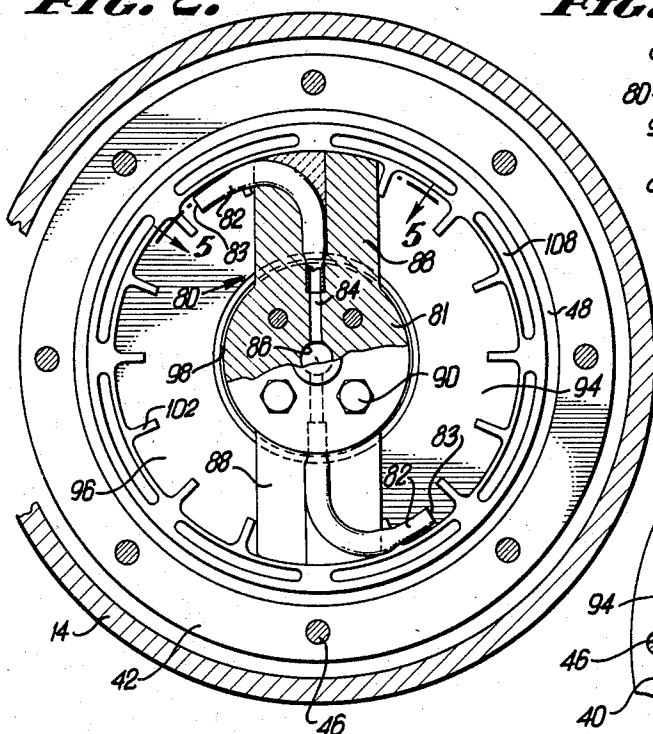
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HIGH SPEED DYNAMIC FLUID PUMP

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FIG. 2.



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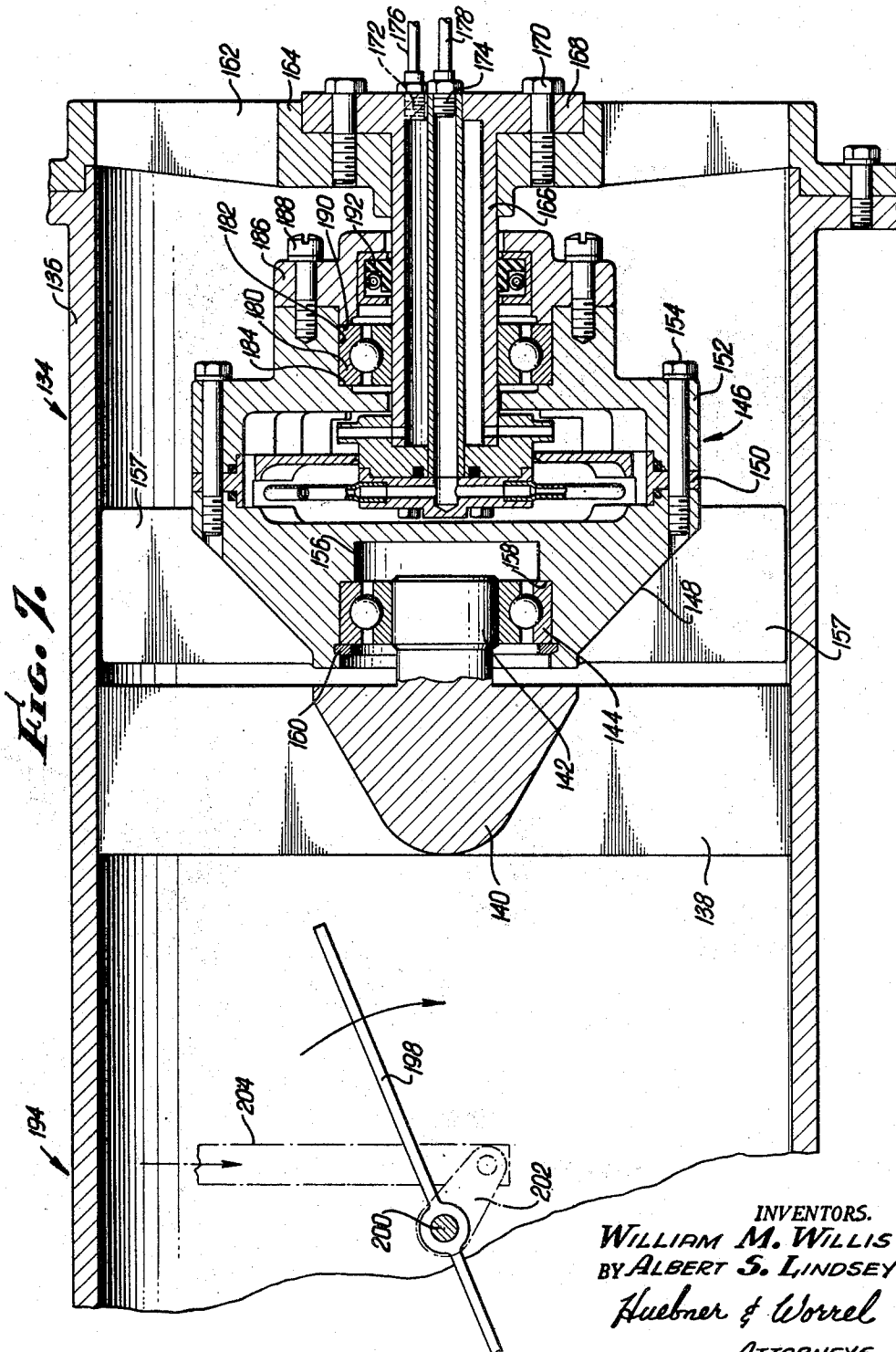
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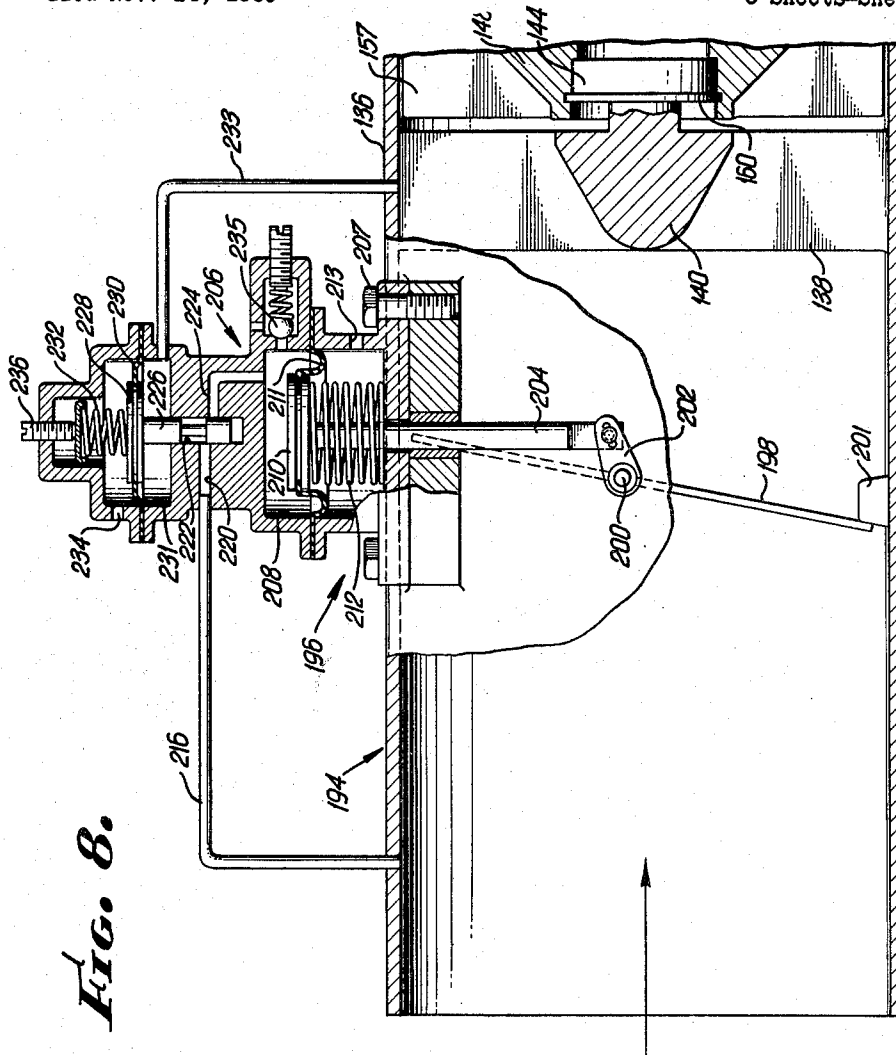


Fig. 8.

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FIG. 9.

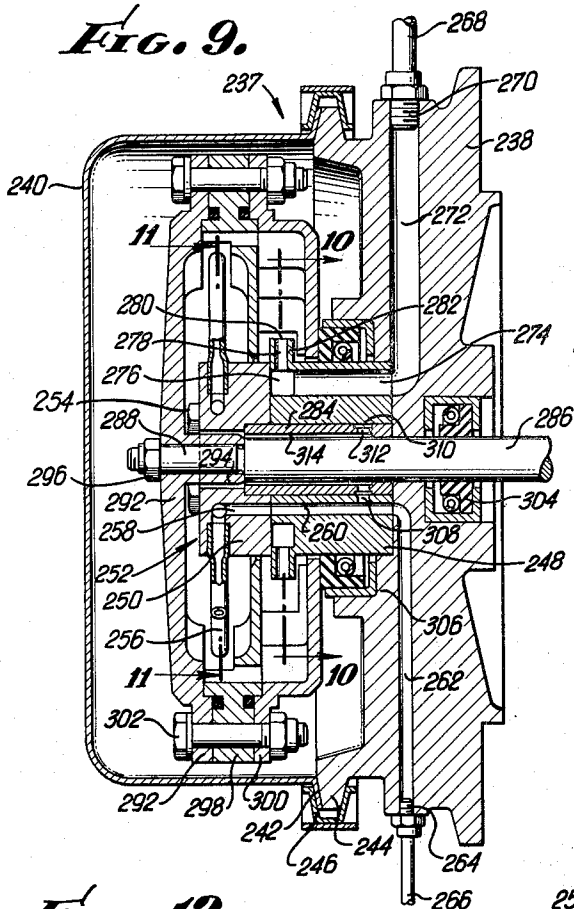


FIG. 10.

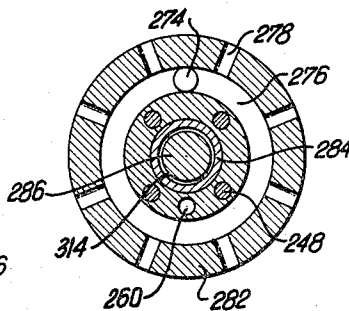


FIG. 11.

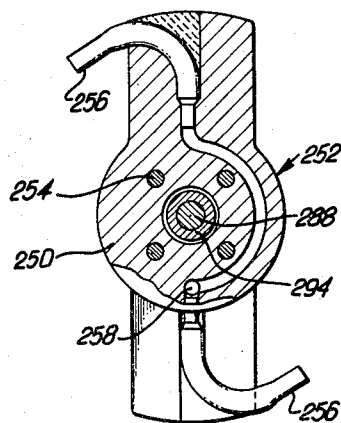
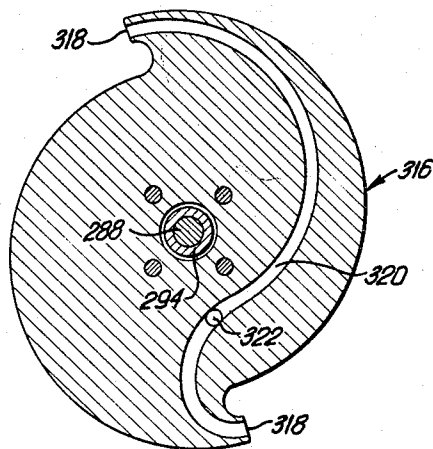


FIG. 12.



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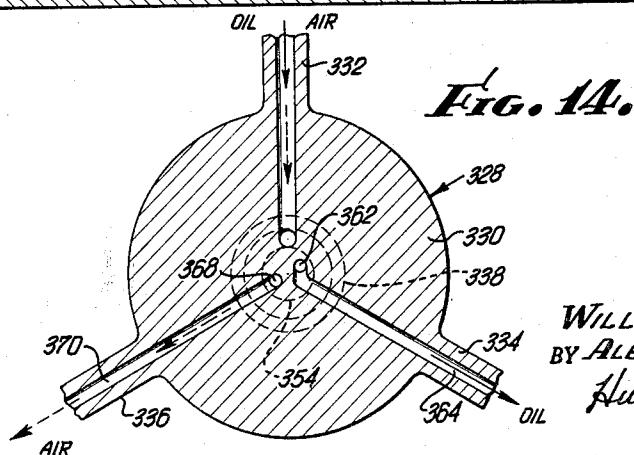
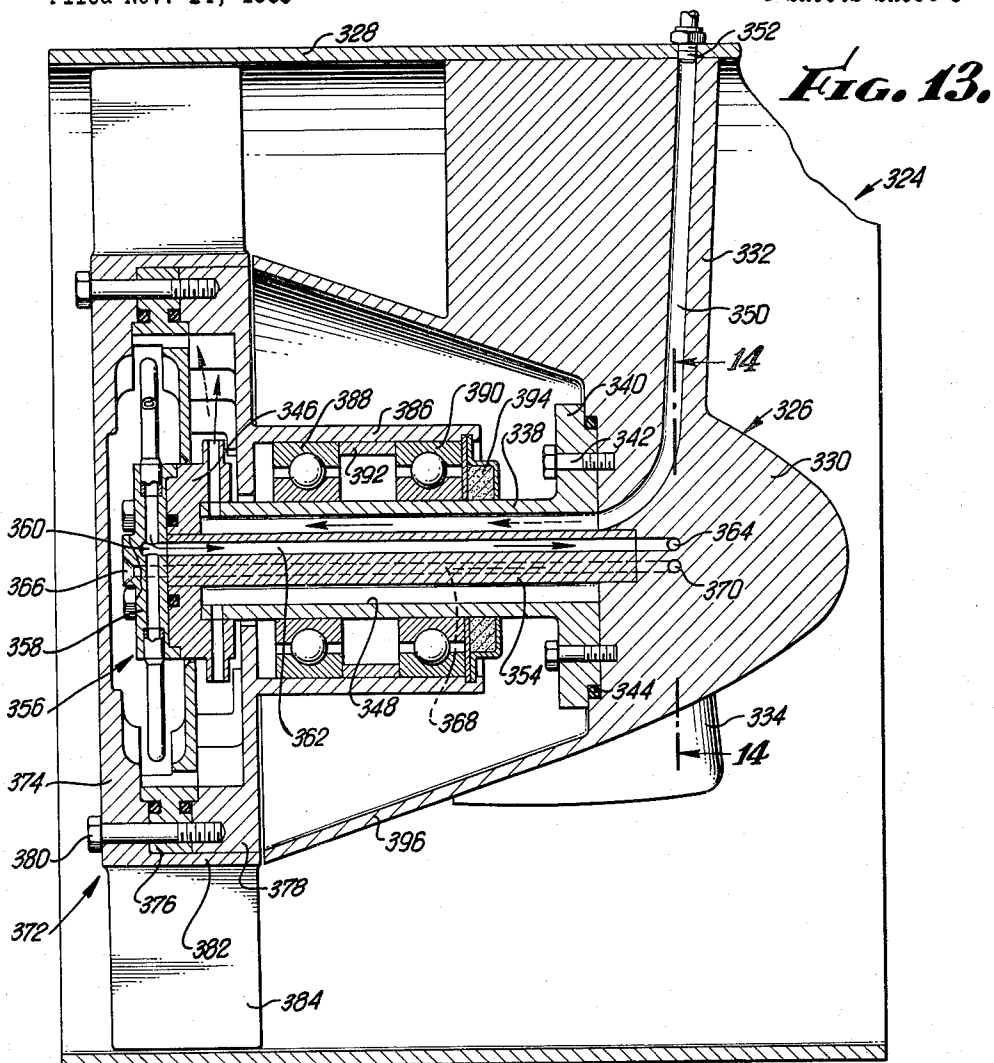
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HIGH SPEED DYNAMIC FLUID PUMP

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20 Claims. (Cl. 103—87)

The present invention relates to fluid pumps, and it relates particularly to a novel high-speed, high-pressure fluid pump of the type having a rotating outer case and a fixed pitot element in the dynamic fluid cavity of the rotating case.

In many fluid pump applications the available rotary power source for driving the pump comprises a high-speed turbine or the like which operates at speeds greatly in excess of the speeds at which conventional fluid pumps can be reliably operated, which requires gearing down of the turbine shaft speed to meet pump requirements. Also, high-speed turbine equipment has a torque and power output generally proportional to the speed of rotation, so that the available torque and power of such a turbine is often inadequate at low turbine speeds to meet the requirements of conventional gear driven pumps.

There has accordingly been a great need in the art for a fluid pump which is capable of being directly driven at high turbine speeds, on the order of 40,000 r.p.m. and higher, which has torque and power requirements that generally match the torque and power which are available in high-speed turbine equipment. One example of the need for such a pump is in missile applications where a small high-speed turbine is employed for providing auxiliary and accessory hydraulic and electrical power. Turbine shaft speeds of about 48,000 r.p.m. are typically for such applications, and speeds of 72,000 r.p.m. and higher are in development. Present alternators and generators for providing auxiliary or accessory electrical power can operate at full turbine shaft speed, and if a compact fluid pump can also be employed to operate at full shaft speed, present requirements of gearing to accommodate a low-speed pump can be completely eliminated.

Another application where it is desirable to employ a fluid pump capable of operating at speeds greatly in excess of conventional pump speeds, with pump torque and power requirements building up according to increases in the speed from a free breakaway torque, is in a ram air driven auxiliary hydraulic pressure source for air craft wherein the device may be lowered directly into the airstream to provide auxiliary hydraulic power within a matter of seconds in the event of power failure in the main hydraulic system.

In view of these and other problems in the art, it is an object of our present invention to provide a novel high-speed, high-pressure fluid pump of the type having a rotating outer case and a fixed pitot element in the dynamic fluid cavity of the rotating case.

Another object of the present invention is to provide a high-speed dynamic fluid pump of the character described which includes novel fluid input means for stabilizing the inside fluid level within the rotating pump case at a level radially outwardly disposed relative to the pitot hub, so as to minimize internal drag and increase pumping efficiency. It is also an object to provide increased pumping efficiency by means of a highly streamlined pitot element which minimizes losses from fluid turbulence, shear and shock waves.

Another object of the present invention is to provide a high-speed dynamic fluid pump of the character described having a free breakaway torque which permits fast acceleration, with torque and power requirements which build up according to the speed at which the pump is

driven, the pump torque and power requirements at various pumping speeds closely matching the corresponding torque and power available in high-speed turbine equipment, whereby the pump is ideal for direct turbine shaft-driven applications.

Another object of our present invention is to provide a high-speed dynamic fluid pump of the character described which is capable of being run dry for unlimited periods without damage.

It is also an object to provide a high-speed fluid pump of the character described wherein substantially complete oil-air separation is achieved within a fraction of a second after the pump commences to operate.

A further object is to provide a high-speed dynamic fluid pump of the character described which is relatively compact and small in size for the amount of pressure and fluid volume pumped, and which is suitable for pumping almost any type of fluid. The present pump is particularly useful for pumping liquid fuels, oil for lubricating or hydraulic purposes, hydraulic fluid, water, and even liquid metals, which are usually very difficult to pump due to cavitation and abrasion problems.

Further objects and advantages of this invention will appear during the course of the following part of this specification wherein the details of construction and mode of operation of a preferred embodiment are described with reference to the accompanying drawings, in which:

FIG. 1 is an axial section illustrating internal details of construction of a presently preferred embodiment of the invention.

FIG. 2 is a cross-sectional view taken on the line 2—2 in FIG. 1 showing details of the dynamic fluid cavity and of the fluid transfer ports leading thereto, and illustrating one form of pitot element employed.

FIG. 3 is a cross-sectional view along the line 3—3 in FIG. 1 illustrating details of our novel inlet hub construction and of the dynamic inlet cavity.

FIG. 4 is a fractional cross-sectional view along the line 4—4 in FIG. 1 illustrating further details of the rotating pump case and dynamic cavity therein.

FIG. 5 is a sectional view along the line 5—5 in FIG. 2 particularly illustrating the pitot element and inlet hub in plan view.

FIG. 6 is an end elevation view, partly in section, showing an alternative form of pitot element.

FIG. 7 is an axial sectional view illustrating a ram air driven embodiment of the present invention.

FIG. 8 is an axial section, partly in elevation, of the ram air driven pump shown in FIG. 7, but particularly illustrating an airflow by-pass valve construction adapted to by-pass any air beyond that available at minimum flight speeds.

FIG. 9 is an axial section illustrating a further embodiment of the present invention which employs journal bearing mounting of the rotating dynamic case.

FIG. 10 is a cross-sectional view along the line 10—10 in FIG. 9 illustrating the structural details of the inlet hub and showing the outlet passage.

FIG. 11 is a cross-sectional view along the line 11—11 in FIG. 9, illustrating the pitot element and its mounting in the embodiment shown in FIG. 9.

FIG. 12 is a sectional view showing another form of pitot element which may be employed in the embodiment of FIG. 9.

FIG. 13 is an axial section illustrating another ram air driven embodiment of the present invention which embodies a separate air bleed-off passage from the central region of the dynamic cavity.

FIG. 14 is a cross-sectional view along the line 14—14 in FIG. 13 illustrating the relationship of the fluid inlet, fluid outlet and air bleed-off passages.

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The pump 10 shown in FIGS. 1-5 of the drawings is of a pad mounted type adapted to be driven by the output shaft of a high-speed turbine 12.

Pump 10 includes a cup-shaped housing 14 having a radially outwardly directed mounting flange 16 at its open end to permit attachment of housing 14 to a suitable support plate or pad 18 as by bolts 19.

In the pump embodiment of FIGS. 1-5 the rotating pump case is mounted on one end of a shaft that is rotatably supported in a cantilevered bearing arrangement. To this end, a bearing support member 20 is provided, and includes an annular plate portion 22 and a cylindrical hub portion 24. The plate portion 22 of bearing support member 20 is mounted just inside of the open or base end of the cup-shaped housing 14, being supported between a housing shoulder 26 and a retainer ring 28. The pump shaft 30 is rotatably mounted in the inner races of a pair of axially spaced bearings 32 and 34 which are supported within the bearing support hub 24. The outer end of shaft 30 is coupled with turbine shaft 11 so as to be driven thereby.

The inner end of shaft 30 is flanged to provide an annular mount plate 36 which supports the rotating pump case 38 as by bolts 39. For simplicity of manufacture it is preferable to make case 38 in three annular sections, an end plate 40 which is secured to the mount plate 36, an intermediate case section 42 and an inner case section 44, the three case sections 40, 42 and 44 being clamped together by a plurality of peripherally arranged bolts 46. Suitable annular seals 48 may be provided between case sections 40 and 42 and between case sections 42 and 44.

A stationary support rod 50 is mounted on the closed end portion of the cup-shaped housing 14 so as to extend into housing 14 in axial alignment with shaft 30 and case 38, support rod 50 extending axially into the inner case section 44. Support rod 50 is provided with integral annular mounting flange 52 for attachment of rod 50 to the housing 14 by bolts 54 or other suitable means.

Stationary support rod 50 has an outer cylindrical surface 56 which is engaged by a fluid seal 58 mounted within the case section 44. Sealing means 58 is radially inwardly disposed relative to the fluid level within case 38 when the pump is operating, and is therefore only required to seal against foaming or static leakage, so that seal 58 may merely comprise a low-pressure type of seal. In fact, it is preferable to employ a seal 58 which will permit axial bleed-off of air that is centrifuged out of the liquid in rotating case 38 during operation of the pump.

The stationary support rod 50 includes an internal axial bore 60 which forms the fluid inlet conduit for the pump as hereinafter described.

Fixedly mounted on the inner end of stationary support rod 50 is a stationary inlet hub 62 which extends substantially radially outwardly of the outer cylindrical surface 56 of support rod 50, terminating at its outer edge in peripheral wall 64. Hub 62 includes a plurality of inlet passages 66 arranged as radial spokes, the inner ends of passages 66 communicating with axial bore 60 of support rod 50, and the outer ends of passages 66 terminating in inlet orifices 68 at the peripheral wall 64 of hub 62.

A web portion 70 of inlet hub 62 closes off the inner end of the axial bore 60 of support rod 50, and an axial opening 72 through web portion 70 receives the inner end of a fixed fluid outlet tube 74. Outlet tube 74 extends axially outwardly through the bore 60 in support rod 50, the outer end of the outlet tube 74 being supported in the closed outer end of fixed support rod 50.

The closed outer end of support rod 50 is provided with an inlet port 76 which communicates with axial bore 60, and with an outlet port 78 which communicates with the inside of outlet tube 74.

Stationary Pitot element 80 is fixedly supported on the inner end of inlet hub 62, and includes a central hub or head portion 81 with a pair of diametrically opposed

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Pitot inlet members 82 extending radially outwardly of the hub 81. Pitot inlet members 82 terminate in inlet openings 83, with Pitot passages 84 extending from inlet openings 83 to a central, axial opening 86 in hub 81, opening 86 communicating directly with the inner end of outlet tube 74.

The Pitot element 80 includes diametrically opposed struts 88 which extend radially outwardly from the Pitot hub 81 so as to provide streamlining for the Pitot inlet members 82. These struts 88 are well streamlined in both the leading and trailing edges, and are preferably designated basically to a prandtl-meyer curve of constant velocity so as not to increase fluid laminar velocities, thus minimizing fluid heating due to the elimination of shear in the fluid.

It is to be noted that the Pitot inlet openings 83 are extended substantially forward or upstream of the struts 88 to eliminate shock waves at the immediate Pitot openings. Further, a novel feature of our present Pitot element 80 is that the inlets are 180° apart, or diametrically opposed, thus providing a balancing of the forces on the Pitot element.

The Pitot element 80 may be fixedly attached to inlet hub 62 by any conventional means, as by bolts 90, and a seal 92 may be provided between the Pitot hub 81 and the inlet hub 62.

The dynamic pump cavity 94 is defined axially between case end plate section 40 and wall 96 of intermediate case section 42, and is defined peripherally within case sections 40 and 42. It will be noted that the inner annular edge 98 of the wall 96 of intermediate case section 42 is substantially smaller in diameter than the peripheral wall 64 of inlet hub 62, with a small radial clearance being provided between inlet hub 62 and the inner edge 98 of wall 96.

Vanes 100 and 102 extend into the dynamic pump cavity 94 from case sections 40 and 42, respectively, and are radially positioned proximate the Pitot inlet openings 83. A plurality of the pump cavity vanes 100 and 102 are regularly spaced in a circular array about pump cavity 94, these pump cavity vanes 100 and 102 being best illustrated in FIGS. 1, 2 and 4. Vanes 100 and 102 may be radially oriented as best shown in FIGS. 2 and 4, and these vanes keep the fluid being pumped in the pump cavity 94 rotating at substantially the speed of rotation of the pump case 38. The pitot inlet member 82 sense both the dynamic pressure of this rotating fluid in the case and the centrifugal pressure, the Pitot inlet openings 83 being positioned near the outer peripheral region of the dynamic pump cavity 94 to obtain maximum values of both this velocity pressure and centrifugal pressure. The high centrifugal pressure completely centrifuges out of air from the fluid being pumped within a matter of a fraction of a second from starting of the pump, and completely eliminates all problems of cavitation, which otherwise would be serious under high-speed pumping conditions.

The fluid to be pumped is introduced into the rotating case 38 through inlet port 76, axial bore 60 of stationary support rod 50, and through inlet passages 66 and orifices 68 of inlet hub 62, under sufficient external boost pressure to provide adequate fluid to the case. The fluid passes from inlet orifices 68 of inlet hub 62 into a dynamic inlet cavity 104 within inner case section 44, one side of inlet cavity 104 being defined by the wall 96 of intermediate case section 42. Inlet cavity 104 is provided with a plurality of scoop-shaped vanes 106 which pick up the fluid introduced through inlet orifices 68 and accelerate the fluid to substantially the rotational speed of the case. Pick-up vanes 106 are mounted within the inner case section 44, in regularly spaced circular array, and the scoop shape of vanes 106 immediately draws the fluid radially outwardly from the inlet orifices 68 so as to reduce turbulence in the region of orifices 68.

The fluid passes from inlet cavity 104 through a plu-

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rality of axially directed fluid transfer ports 108 which introduce the fluid into the outer peripheral extremity of the dynamic pump cavity 94. By thus introducing the fluid into the actual dynamic pump cavity 94 at its peripheral extremity, drag effect of the rotating fluid on the pitot element 80 is minimized.

Drag effect of the fluid on the Pitot element is further greatly minimized by the built-in level control which is provided by our novel inlet hub construction. It will be noted that the inlet orifices 68 of inlet hub 62 are positioned at a substantially larger diameter than the general hub section which includes the hub portion 81 of pitot element 80. By this means, when the static "fluid pressure" in the rotating pump case 38 at the diameter of inlet orifices 68 is equal to or greater than the boost pressure of the incoming fluid which enters the rotating case through inlet orifices 68, shut-off of incoming fluid will occur, whereby a uniform, accurate fluid level will be established during pumping slightly radially inwardly of the inlet orifices 68, but substantially radially outwardly of the Pitot hub 81. By this means, the only stationary elements which are exposed to high velocity fluid are the circular outer edge of the inlet hub 62 and the highly streamlined Pitot struts 88 and Pitot inlet members 82. This built-in level control has been found to provide greatly increased pumping efficiency and uniformity over prior art pumps of this general character.

Any one of a number of various external control mechanisms may be employed in connection with our high-speed dynamic fluid pump, including but not limited to pressure outlet sensing means coupled with the turbine as an overspeed control limiting turbine speed; pressure regulating valve means sensing output pressure to control the amount of fluid provided to the pump inlet; and pressure by-pass valve means connected to the pump output which would regulate the pressure delivered to the system to any desired pressure, as, for example, 3,000 p.s.i., by-passing any excess pressure beyond this. Such regulating mechanisms are well known in the art, and are accordingly not set forth in detail herein.

Some external plumbing has, however, been shown in FIG. 1 to illustrate how much regulating means can readily be coupled with the present invention.

Fluid inlet tube 110 and fluid outlet tube 112 are connected to respective pump inlet and outlet ports 76 and 78. A pressure regulator valve 114 has been illustrated in FIG. 1 as being interposed in the fluid inlet line 110, pressure regulator 114 being conveniently mounted on the closed end of the cup-shaped housing 14. Fluid passage means 116 connects outlet tube 112 with pressure regulator valve 114. Pressure regulator valve 114 may be adjusted so that when the outlet pressure in fluid outlet tube 112 and in passage means 116 becomes greater than a preselected pressure, the regulator valve 114 will decrease the amount of inlet fluid which is permitted to pass to the pump through fluid inlet tube 110.

Also shown in FIG. 1 is a pressure sensing line 118 which is connected to fluid outlet tube 112, and which may be connected to control means associated with turbine 12 so as to provide an overspeed control for turbine 12. For example, where turbine 12 comprises a gas turbine engine, the pressure sensing line 118 may be connected to throttle means which controls the speed of turbine 12. Such an overspeed turbine control is particularly adaptable for use in connection with the present dynamic fluid pump because of the fact that the output pressure and power requirements of the pump are substantially directly proportional to the speed of rotation of the pump, and because of the similarity between the power output curve for a turbine and the power requirement curve for the pump.

An alternative form of Pitot element 120 has been shown in FIG. 6, the Pitot element 120 being usable in

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the pump shown in FIGS. 1-5 as a replacement for the Pitot element 80.

Pitot element 120 includes a central hub portion 122 with diametrically opposed peripheral inlet openings 124, conduits 126 curving inwardly from respective inlet openings 124 so as to communicate with central opening 128, which in turn communicates with the fixed outlet tube 74. The alternative Pitot element 120 has a nebular configuration, with a tapered outer portion 130 and with the inlet openings 124 extended forwardly of respective sharp leading edges 132.

In FIGS. 7 and 8 of the drawings we have shown an alternative embodiment of the present invention which comprises a ram air driven pump 134 of a type suitable for providing auxiliary hydraulic power for aircraft.

Pump 134 is preferably mounted in an open-ended tubular housing 136. The front end of pump 134 is supported by means of a streamlined support strut 138 which extends diametrically across tubular housing 136 and which is provided with a central hub portion 140. Extending axially rearwardly from the hub 140 is a bearing support post or boss 142 which supports the inner race of front bearing 144, the front end of rotating case 146 being supported on the outer race of bearing 144.

The rotating case 146 includes front case section 148, intermediate case section 150 and rear case section 152, these three rotating case sections being joined together by circularly arranged peripheral bolts 154. It will be noted that the front case section 148 has substantial axial depth to permit streamlining thereof.

Front case section 148 is provided with a forwardly directed, axially arranged annular recess 156 for receiving the outer race of bearing 144, bearing 144 being positioned between a forwardly facing shoulder 158 and a locking ring 160 in recess 156.

A plurality of turbine blades 157 are integrally connected to front case section 148, projecting radially outwardly from case section 148, ram air which passes through tubular housing 136 driving the turbine blades 157 to rotate the pump case 146.

A streamlined rear support strut 162 extends diametrically across the tubular housing 136, and is provided with an axial hub portion 164 upon which stationary support rod 166 is mounted. Support rod 166 includes annular flange portion 168 which may be fastened to hub 164 by bolts 170. Inlet and outlet ports 172 and 174, respectively, are provided at the rear of the stationary support rod 166, and connect to fluid inlet and outlet lines 176 and 178, respectively.

It will be noted that the various internal details of construction of the ram air driven pump 134 shown in FIGS. 7 and 8 are similar to the corresponding portions of pump 10 shown in FIGS. 1-5, so that a detailed description of the internal construction is unnecessary in connection with pump 134. However, it is to be noted that pump 134 embodies straddle-mounted bearings, with the rotating case 146 supported on the outer bearing races, as distinguished from the cantilevered bearing arrangement of pump 10 as shown in FIG. 1, wherein the case support shaft 30 is mounted on the inner bearing races.

Thus, as shown in FIG. 7, the rear bearing 180 of pump 134 has its inner race mounted on the stationary support rod 166, with its outer race mounted in the rear case section 152, within an annular recess 182. The outer race of bearing 180 is seated between an annular shoulder 184 in rear case section 152 and a shoulder 190 on a seal support member 186 which is affixed to the rear end of rear case section 152 as by screws 188. A low-pressure fluid seal 192 is supported in seal support member 186 and engages against the stationary support rod 166, seal 192 functioning similarly to the seal 58 of pump 10 as shown in FIG. 1.

It is to be noted that one of the big advantages of the present invention as employed in the ram air driven application of FIGS. 7 and 8 is the fact that variable in-

cident turbine driving blades are not required due to the free breakaway torque. An additional advantage of this free breakaway torque in the ram air driven application is that the pump accelerates rapidly, providing operational fluid outlet pressures within seconds, which is extremely important when the pump is employed as an emergency power source. Pump output pressure builds up so rapidly that the pump is adequate to take care of emergency hydraulic power requirements even where the main hydraulic power source fails during aircraft take-off or landing.

Although an electrical generator or alternator has not been illustrated in connection with the pumps shown in FIGS. 1-6 and in FIGS. 7 and 8, it is to be understood that such electrical power sources will in many instances be coupled with the pump so as to be driven synchronously therewith.

It is desirable to design the ram air driven pump embodiment 134 so that it will provide the required fluid pressure output for a pump speed corresponding to minimum flight speed conditions, and to provide a cooperating airflow regulating valve upstream of the pump so as to by-pass any air beyond that which is present at minimum flight speeds. In addition, it is also desirable to employ some fluid pressure regulating means responsive to pump output pressure, which may be of the type shown and described in connection with FIG. 1.

Although the airflow regulating valve means may be of any desired type capable of by-passing excess air, one suitable arrangement has been shown in detail in FIG. 8.

A portion 194 of housing 136 extends forwardly of the pump 134, the airflow regulating valve means 196 being mounted on this forward housing portion 194. The valve means 196 includes a valve closure element 198, which may be of the "butterfly" type, pivotally mounted on a diametrically positioned shaft 200 within housing portion 194. The valve closure element 198 is adapted to pivot between an open position as shown in FIG. 7 to provide substantially all of the available ram air to the turbine blades 157 for minimum flight speed conditions, and a closed position as shown in FIG. 8 for admitting only a small percentage of the available ram air to the turbine blades for high-speed flight conditions. Stop means 201 may be provided on the inner wall of housing portion 194 to limit the closing movement of valve closure element 198, so as to admit the desired amount of ram air through the tubular housing 136 when valve closure element 198 is in the "closed" position.

The shaft 200 projects outwardly of forward housing portion 194, and is provided with an integral arm 202 which is actuated by means of an actuating plunger 204 pivotally connected to arm 202. The plunger 204 extends into a valve housing 206 which may be mounted externally on forward housing portion 194 as by bolts 207.

Actuating plunger 204 extends into a chamber 208 within valve housing 206, plunger 204 having a plunger head 210 which is attached in sealing engagement with the central portion of a flexible diaphragm 211 extending across chamber 208. A biasing spring 212 urges plunger head 210 and plunger 204 upwardly so as to bias the valve closure element 198 toward its closed position as shown in FIG. 8. A relief port 213 vents the chamber 208 below diaphragm 211 to the atmosphere.

It will thus be seen that biasing spring 212 will normally hold the closure element 198 in the closed position of FIG. 8, the closure element 198 being rotated clockwise in FIGS. 7 and 8 toward its open position upon the introduction of air under pressure into the chamber 208 above diaphragm 211 so as to move plunger 204 downwardly.

A pressure line 216 communicates with the inside of forward housing portion 194 forwardly or upstream of valve closure element 198, and is connected to a passage 220 in housing 206 which in turn communicates, through a bore 222, with a passage 224 which leads to chamber

208 above diaphragm 211. A control plunger 226 is slidably mounted in bore 222, and when plunger 226 is in its lowermost position, air pressure is applied from line 216 through passage 220, through bore 222 and through passage 224 into chamber 208 to urge plunger 204 downwardly to open the closure element 198. However, as the control plunger 226 is moved upwardly from this lowermost position, it will gradually block off the communication between passages 220 and 224, thus reducing the air pressure applied above diaphragm 211 in chamber 208, permitting biasing spring 212 to urge closure element 198 toward its closed position.

Control plunger 226 is provided with an integral plunger head 228 which is connected to a diaphragm 230 which extends across a chamber 231 in housing 206. A biasing spring 232 normally urges control plunger 226 downwardly so as to open the connection between passages 220 and 224. A pressure sensing line 233 communicates with the inside of the tubular housing 136 rearwardly or downstream of valve closure element 198, and is connected to chamber 231 below diaphragm 230, so that increases in pressure downstream of valve closure element 198 will oppose the biasing force of spring 232, causing upward movement of control plunger 226. A relief port 234 vents the chamber 231 above diaphragm 230 to the atmosphere. An adjusting screw 236 in housing 206 adjusts the force of spring 232 on plunger head 228, thus adjusting the sensitivity of the valve to pressure sensed through line 233.

If desired, an adjustable pressure relief valve 235 may be provided in connection with chamber 208 above diaphragm 211 to limit the amount of pressure applied to diaphragm 211.

Operation of the airflow regulating valve means 196 is as follows: Under low flight speeds conditions, the pressure sensed through line 233 will be relatively low, whereby the pressure in chamber 231 below diaphragm 230 will be insufficient to overcome the force of biasing spring 232, and the control plunger 226 will therefore be in its lowermost position. This will permit air pressure to be applied from line 216 through passages 220 and 224 into chamber 208, thus to force plunger 204 downwardly, moving closure element 198 to its open position as shown in FIG. 7, thereby admitting a maximum amount of ram air to the pump. Increased pressure sensed through line 233 will increase the pressure in chamber 231 below diaphragm 230, thereby moving control plunger 226 upwardly against the force of biasing spring 232, partially closing the connection between passages 220 and 224 and thereby reducing the pressure admitted to chamber 208, permitting biasing spring 212 to move valve closure element 198 toward its closed position, closure element 198 being moved to its most fully closed position as shown in FIG. 8 when sufficient pressure is sensed through line 233 under high flight conditions.

In FIGS. 9-12, inclusive, a further embodiment 237 of the invention is illustrated, this embodiment employing a journal type bearing for the mounting of the rotating pump case.

The pump 236 includes a housing comprising a base member 238 and a cup-shaped cover member 240, the cover member 240 having an outwardly directed flange 242 at its open end which seats against a flange 244 on the housing base member 238, the flanges 242 and 244 being clamped together by a V-clamp 246.

A stationary support member 248 is fixedly attached to housing base member 238, and the hub portion 250 of Pitot element 252 is fixed to stationary support member 248 as by bolts 254. Pitot element 252 is generally similar in construction to Pitot element 80 of the embodiment shown in FIGS. 1-5. However, the Pitot inlet members 256 are connected to an outlet passage 258 in the hub position 250 which is spaced a substantial distance from the central axis of Pitot element 252, this being required because of the fact that the rotating pump shaft

extends axially through the stationary support member 248 and the hub portion 250 of the Pitot element.

Pitot outlet passage 258 communicates with an outlet passage 260 which extends through the stationary support member 248, passage 260 in turn communicating with outlet passage 262 in housing base member 238. Passage 262 terminates at outlet port 264, to which outlet conduit 266 is connected.

Inlet conduit 268 connects with inlet port 270, inlet fluid then passing through passage 272 in housing base member 238 and connecting passage 274 in stationary support member 248, passage 274 terminating at annular inlet channel 276 at the inner end of stationary support member 248. Inlet passages 278 extend radially outwardly from inlet channel 276, being arranged as radial spokes, and terminate at inlet orifices 280 in the outer periphery of inlet hub 282. Thus, the inlet orifices 280 function in a similar manner as the corresponding inlet orifices 68 of the embodiment of the invention shown in FIGS. 1-5.

A journal bearing 284 is axially supported within stationary support member 248 and within pitot hub 250, the pump shaft 286 being rotatably supported in journal bearing 284 and extending outwardly through housing base member 238. Shaft 286 is provided with an integral spindle portion 288 which projects outwardly through pitot hub 250, and upon which the rotating case 290 is fixedly secured. The end plate section 292 of the rotating case 290 includes an axial hub portion 294 which is mounted on shaft spindle 288, being secured thereon as by nut 296. Intermediate and inner case sections 298 and 300, respectively, are secured to end plate section 292 by peripherally arranged bolts 302.

A fluid seal 304 is provided between inner case section 300 and the outer periphery of stationary support member 248. A second fluid seal 306 is provided between housing base member 238 and shaft 286. These seals 304 and 306 may comprise low-pressure seals similar to the seal 58 of FIG. 1.

In order to provide adequate lubrication between journal bearing 284 and shaft 286 for high-speed operation of the pump, it is preferred to provide lubricating fluid directly from the high-pressure side of the pump, the lubricating fluid comprising the same fluid as that being pumped. To this end, an opening 308 extends radially inwardly from outlet passage 260 through the inner wall of stationary support member 248, and communicates with an annular channel 310 in the outer wall of journal bearing 284. A plurality of openings 312 extend radially inwardly from channel 310 through journal bearing 284 so as to communicate with lubrication clearance 314 within the journal bearing 284. In this manner, high-pressure fluid is provided in ample quantity directly from the high-pressure outlet passage 260 to the lubricating clearance 314 within the journal bearing.

An alternative pitot element 316 which may be employed in connection with the pump shown in FIGS. 9 and 10 has been illustrated in FIG. 12. This alternative pitot element 316 is similar in external configuration to the pitot element 120 shown in FIG. 6, but the inlet openings 318 are connected through passage 320 to pitot outlet passage 322 which is substantially spaced from the central axis of pitot element 316.

FIGS. 13 and 14 illustrate another embodiment 324 of the present invention which is of the ram air driven type. Pump support member 326 is mounted within open-ended housing 328, support member 326 including a central hub portion 330 and three radially outwardly extending spoke portions 332, 334 and 336 which are attached to the inside of housing 328 at their outer ends. The support member 326 is positioned near the forward or upstream end of housing 328. Stationary support sleeve 338 extends rearwardly from the hub portion 330 of support member 326, support sleeve 338 having a radially outwardly projecting flange 340 at its forward end which is attached to support member 326 as by

bolts 342. A sealing ring 344 may be engaged between the flange 340 and the hub portion 330 of support member 326.

The inlet hub 346 is fixedly mounted on the inner end of stationary support sleeve 338, support sleeve 338 having an axial bore 348 therethrough which communicates with inlet hub 346 to provide inlet fluid conduit means. Inlet fluid is provided to bore 348 through inlet passage 350 which extends from inlet port 352 through spoke portion 332 and hub portion 330 of support member 326.

A central rod 354 extends axially through the bore 348 of stationary support sleeve 338, connecting at its inner end to Pitot element 356 at the pitot hub 358, and connecting at its outer end to the hub portion 330 of support member 326.

The Pitot outlet passage 360 communicates with an outlet passage 362 that extends axially through central rod 354 and connects at the outer end of rod 354 with outlet passage 364, which leads through hub portion 330 and spoke portion 334 of support member 326, terminating at its outer end with a suitable outlet port (not shown).

Separate air bleed-off conduit means is provided in the embodiment of the invention shown in FIGS. 13 and 14, and includes air bleed-off opening 366 in pitot hub 358 which communicates with the inside of the dynamic fluid cavity in the central region of the cavity. Bleed-off opening 366 communicates with air bleed-off passage 368 extending axially through central rod 354, and communicating at the outer end of rod 354 with bleed-off passage 370 extending through hub portion 330 and spoke portion 336 of support member 326, the bleed-off passage 370 opening to the atmosphere.

The rotating case 372 includes outer, intermediate and inner case sections 374, 376 and 378, respectively, which are secured together by peripherally arranged bolts 380, the outer case section 374 including a peripheral flange portion 382 which extends axially forwardly over the peripheral portions of the other case sections 376 and 378 and upon which are mounted a plurality of turbine blades 384 which are driven by ram air passing through the housing.

Inner case section 378 includes a cylindrical axial sleeve portion 386 which is supported on the outer races of a pair of axially spaced anti-friction bearings 388 and 390, the inner bearing races being supported on the stationary support sleeve 338. Bearings 388 and 390 are separated by a spacer ring 392. A suitable fluid seal 394 is mounted in the forward end of sleeve 386 and engages against the outer wall of stationary support sleeve 338.

It is to be noted that the rotating case 372 is mounted on the outer bearing races of the bearings 388 and 390, in a cantilevered mounting arrangement.

The support member 326 is preferably streamlined, having a streamlined hub portion 330 and streamlined spoke portions 332, 334 and 336. It is also preferable to include as a part of support member 326 a rearwardly extending conical shield 396 which terminates at its rear edge immediately adjacent to the forward edge of the flange portion 382 of outer case section 374.

It is particularly desirable to employ separate air bleed-off conduit means such as that shown in FIGS. 13 and 14 where the pump is to be used in a scavenge type of system in which a high volume mixture of air and oil would be present.

It is still advantageous to provide for oil-air separation where the pump is to be used in a hydraulic system in which very little air is present, so as to eliminate compressive media from the non-compressible hydraulic fluid. However, in this case the oil-air separation can be accomplished without the need for the separate air bleed-off conduit means by employing a novel construction of the interior of the pump case. This construction which

is best illustrated in FIGS. 1 to 5 of the drawings, is as follows:

The vanes 106 in the inlet cavity 104 extend radially inwardly farther than the vanes 100 and 102 in the dynamic pump cavity 94, whereby the rotational speed of the liquid will be slightly higher in the inlet cavity 104 than in the pump cavity 94. This will produce a recirculation of air (in the form of foam) from the pump cavity 94 to the inlet cavity 104 through the narrow annular gap between inlet hub 62 and the inner edge 98 of inside case wall 96. This recirculation of air from pump cavity 94 back to the inlet cavity 104 prevents air pressure buildup inside the pump cavity 94 to an extent which would cause the liquid level to move radially outwardly until the Pitot inlet openings 83 are uncovered from the liquid, causing the pump to stall momentarily until the air is discharged. However, the restriction of the controlled annular gap between inlet hub 62 and the inner edge 98 of wall 96 will produce a slightly higher pressure on the liquid surface in the pump cavity 94 than on the liquid surface in the inlet cavity 104, thus reducing drag on the Pitot element 80.

The air which is thus recirculated back to the inlet cavity 104 from the pump cavity 94 will ultimately bleed out of the case through the low-pressure seal 58.

While the instant invention has been shown and described herein, in what are conceived to be the most practical and preferred embodiments, it is recognized that departures may be made therefrom within the scope of the invention, which is therefore not to be limited to the details disclosed herein, but is to be accorded the full scope of the claims.

Having described our invention, what we claim as new and desire to secure by Letters Patent is:

1. A fluid pump which comprises: support means; a pump case rotatably mounted on said support means, said case having annular cavity means therein; means connected to said case for applying rotary power to said case; annular hub means carried by said support means and axially positioned within said case; a stationary Pitot element mounted on said hub means, said Pitot element having a Pitot inlet member extending radially outwardly of said hub means; fluid outlet conduit means extending from said Pitot inlet member and through said hub means; a stationary inlet member extending radially outwardly from said hub means and axially spaced from said Pitot element within said cavity means, said stationary inlet member having a fluid inlet orifice at its periphery; and fluid inlet conduit means extending through said stationary inlet member to said inlet orifice so as to provide fluid to be pumped into said cavity means through said inlet orifice; whereby blocking of said inlet orifice by rotating fluid in said cavity means will stabilize the inside fluid level within the rotating case at a radius slightly less than the radius of said inlet orifice.

2. A fluid pump as defined in claim 1 wherein said means for applying rotary power to said case includes a shaft connected to said case so as to extend axially outwardly from said case, and turbine drive means connected to said shaft.

3. A fluid pump as defined in claim 1 wherein said means for applying rotary power to said case includes a plurality of turbine blades mounted on said case and annularly arranged about the periphery of the case so as to be driven by ram air passing over the case.

4. A fluid pump as defined in claim 1 which includes a plurality of said inlet orifices regularly spaced about the periphery of said stationary inlet member.

5. A fluid pump as defined in claim 1 which includes a pair of said Pitot inlet members in diametrically opposed relationship.

6. A fluid pump which comprises: support means; a pump case rotatably mounted on said support means, said case having annular cavity means therein; means connected to said case for applying rotary power to said

case; said support means including a stationary support member which extends axially into said rotating case through one end of said case, said support member having an inner end positioned within said cavity means; a stationary Pitot element mounted within said cavity means on said stationary support member adjacent to its said inner end, said Pitot element having a hub portion axially positioned within said cavity means and a Pitot inlet member extending radially outwardly of said Pitot hub portion; fluid outlet conduit means extending from said Pitot inlet member and through said Pitot hub portion; a stationary annular inlet hub member mounted on said stationary support member adjacent to its said inner end and axially positioned within said cavity means; said inlet hub member having a fluid inlet orifice at its periphery; and fluid inlet conduit means extending through said inlet hub to said inlet orifice so as to provide fluid to be pumped into said cavity means through said inlet orifice; whereby blocking of said inlet orifice by rotating fluid in said cavity means will stabilize the inside fluid level within the rotating case at a radius slightly less than the radius of said inlet orifice; said inlet conduit means and said outlet conduit means including respective fluid inlet and outlet passages extending axially within said support member.

7. A fluid pump as defined in claim 6 which includes: air bleed-off passage means extending axially through said support member and opening through said Pitot hub portion into said cavity means.

8. A fluid pump as defined in claim 6 which includes: bearing means mounted on said stationary support member, said case being rotatably supported on said bearing means.

9. A fluid pump as defined in claim 8 wherein said bearing means includes a pair of spaced anti-friction bearing members.

10. A fluid pump as defined in claim 6 which includes: first bearing means mounted on said stationary support member; second bearing means mounted on said support means adjacent to the end of said rotating case opposite to the case end into which said stationary support member extends; said case being rotatably mounted adjacent to its respective ends on said first and second bearing means.

11. A fluid pump as defined in claim 6 which includes: journal bearing means axially disposed within said stationary support member; a shaft axially connected to the end portion of said rotating case opposite to the case end into which said support member extends, said shaft extending axially inwardly through the case and through said Pitot hub portion and being journaled within said journal bearing means.

12. A fluid pump as defined in claim 11 which includes a fluid communication from said fluid outlet conduit means to said journal bearing means to provide lubricating fluid to said journal bearing means.

13. A fluid pump which comprises: support means; a pump case rotatably mounted on said support means, said case having axially spaced annular pumping and inlet cavities therein and having a fluid transfer port communicating between the pumping and inlet cavities proximate the peripheries of the pumping and inlet cavities; means connected to said case for applying rotary power to said case; a stationary Pitot element mounted on said support means within said pumping cavity, said Pitot element having a hub portion axially positioned within said pumping cavity and a Pitot inlet member extending radially outwardly of said Pitot hub portion; fluid outlet conduit means extending from said Pitot inlet member and through said Pitot hub portion; a stationary annular inlet hub member mounted on said support means and axially positioned within said pump case inlet cavity, said inlet hub member having a fluid inlet orifice at its periphery; and fluid inlet conduit means extending through said inlet hub to said inlet orifice so as to provide fluid to be pumped into said

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inlet cavity through said inlet orifice; whereby blocking of said inlet orifice by fluid rotating in said pump case will stabilize the inside fluid level within the rotating case at a radius slightly less than the radius of said inlet orifice.

14. A fluid pump as defined in claim 13 which includes a plurality of said fluid transfer ports annularly arranged within said pump case.

15. A fluid pump as defined in claim 14 which includes a plurality of said inlet orifices regularly spaced about the periphery of said inlet hub member.

16. A fluid pump as defined in claim 15 which includes a pair of said Pitot inlet members in diametrically opposed relationship.

17. A fluid pump as defined in claim 14 wherein said support means includes a stationary support member which extends axially into said rotating case through one end of said case, said support member having an inner end positioned within said cavity means; one end of said case, said inlet hub member and said Pitot hub portion being fixedly secured to said support member proximate its said inner end.

18. A ram air driven fluid pump which comprises: an open-ended tubular housing; support means connected to said housing so as to extend inside of said housing; a pump case rotatably mounted on said support means, said case having annular cavity means therein; a plurality of turbine blades mounted on said case and annularly arranged about the periphery of the case so as to be driven by ram air passing through said housing; a stationary Pitot element mounted on said support means within said cavity means, said Pitot element having a hub portion axially positioned within said cavity means and a Pitot inlet member extending radially outwardly of said Pitot hub portion; fluid outlet conduit means extending from said Pitot inlet member and through said Pitot hub portion; a stationary annular inlet hub member mounted on said support means and axially positioned within said cavity means, said inlet hub member having a fluid inlet orifice at its periphery; and fluid inlet conduit means extending through said inlet hub to said inlet orifice so as to provide fluid to be pumped into said cavity means through said inlet orifice; whereby blocking of said inlet orifice by rotating fluid in said cavity means will stabilize the inside fluid level within the rotating case at a radius slightly less than the radius of said inlet orifice.

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19. A ram air driven fluid pump as defined in claim 18 which includes airflow regulating valve means connected to said housing.

20. A fluid pump which comprises: support means; a pump case rotatably mounted on said support means, said case having annular cavity means therein; wall means in said case dividing said cavity means into axially spaced annular inlet and pumping cavities, said wall means having fluid transfer port means therethrough communicating between said inlet and pumping cavities proximate the peripheries of said pumping and inlet cavities, said wall means having an annular inner edge defining its radially innermost extent; stationary annular hub means in said cavity means and extending through said annular inner edge of said wall means, said hub means proximate said wall means having an outer diameter slightly less than the diameter of said inner edge so as to provide a narrow annular gap between said hub means and said inner edge; a Pitot element mounted on said hub means and extending radially outwardly into said pumping cavity, said Pitot element having fluid outlet conduit means therein terminating at a Pitot inlet opening in said pumping cavity; a stationary inlet member mounted on said hub means and extending radially outwardly into said inlet cavity, said inlet member having fluid inlet conduit means therein terminating at an inlet orifice in said inlet cavity; a plurality of radially extending vanes mounted in said case within said pumping cavity; and a plurality of radially extending vanes mounted in said case within said inlet cavity; said inlet cavity vanes being deeper in a radial direction than said pumping cavity vanes.

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