

[54] **SUBMERGED MULTISTAGE PUMP
USABLE AS PROPULSION UNIT**

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60/332, 415/144

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[58] Field of Search 415/199, 144; 115/16; 60/221,
60/222, 229, 232, 144

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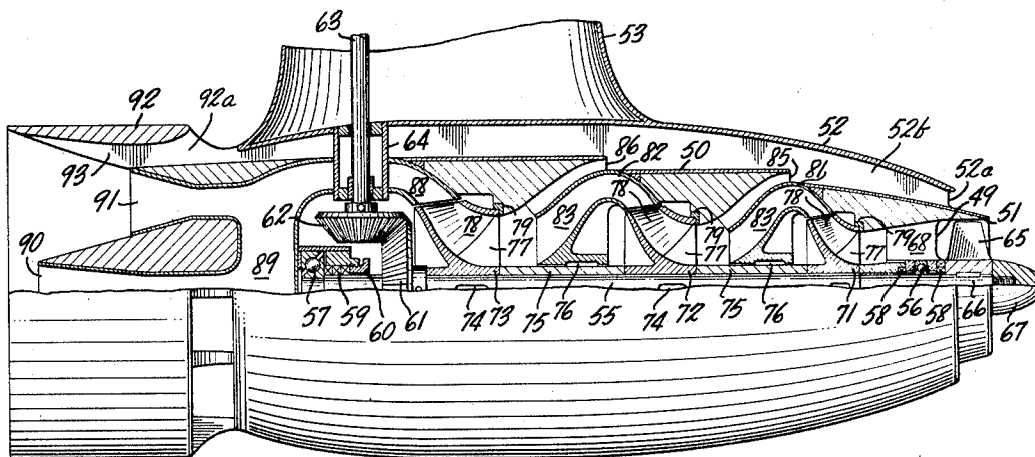
Primary Examiner—Henry F. Raduazo

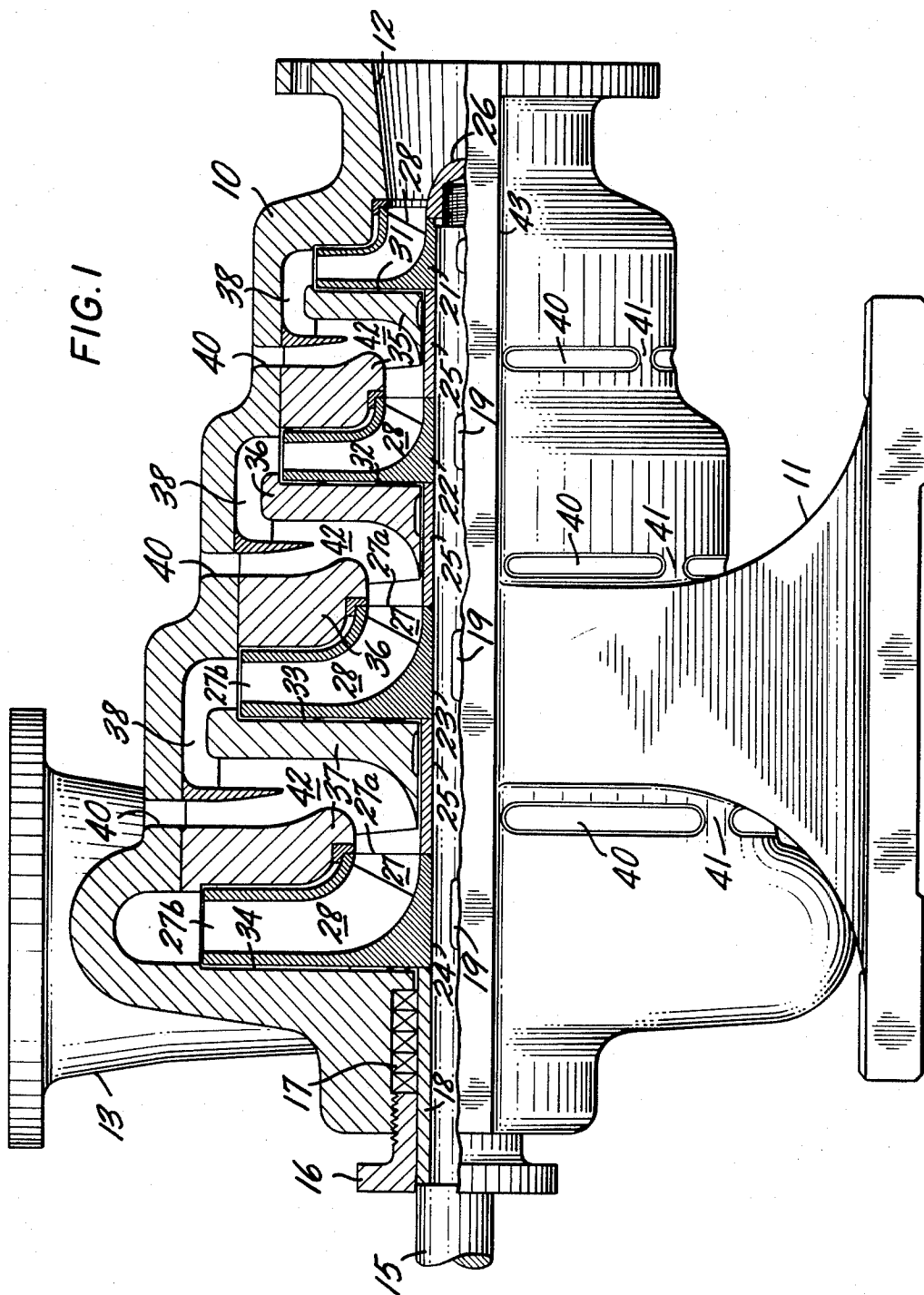
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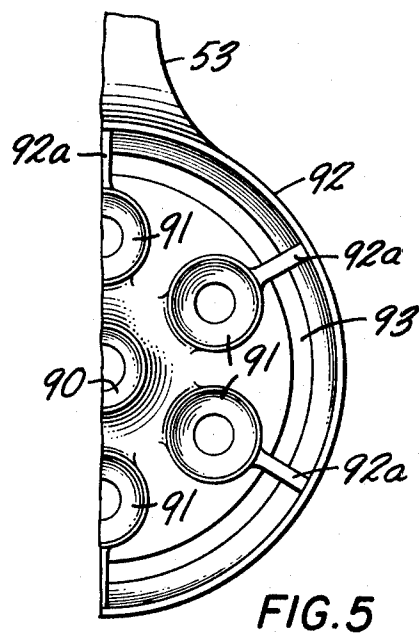
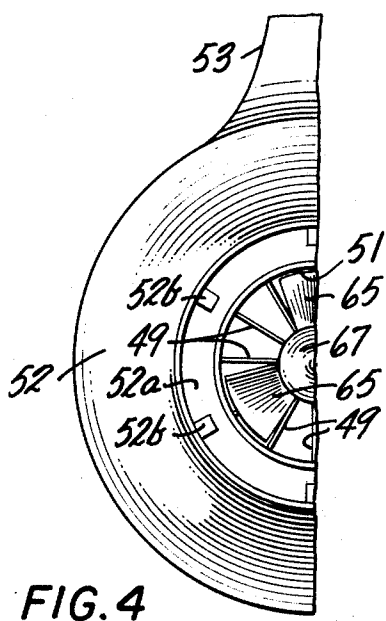
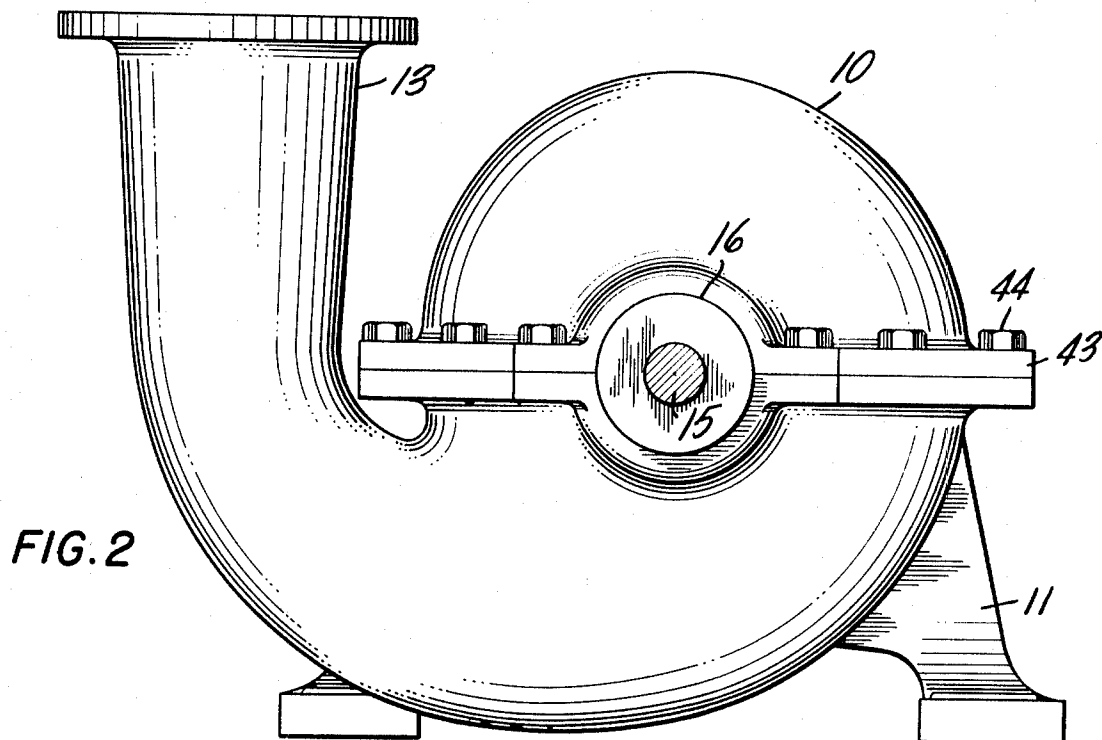
[57] **ABSTRACT**

A submerged pump comprising a plurality of coaxial impellers arranged in series in an elongated casing having an inlet at one end and an outlet at the other and providing a pump chamber for each impeller and connecting passageways between the pump chambers, has additional inlets opening from the exterior of the casing into the connecting passageways between successive pump chambers. The velocity of liquid being pumped is increased by successive impellers and the volume of the liquid is increased by the liquid drawn in through the additional inlets. When used as a submerged propulsion unit the pump is of streamlined configuration and is surrounded by a shroud. Forward and reverse propulsion are selectively provided by directing the pump discharge to rearwardly or forwardly directed nozzles. The pump can also be used as a bow-thruster in a vessel.

10 Claims, 10 Drawing Figures







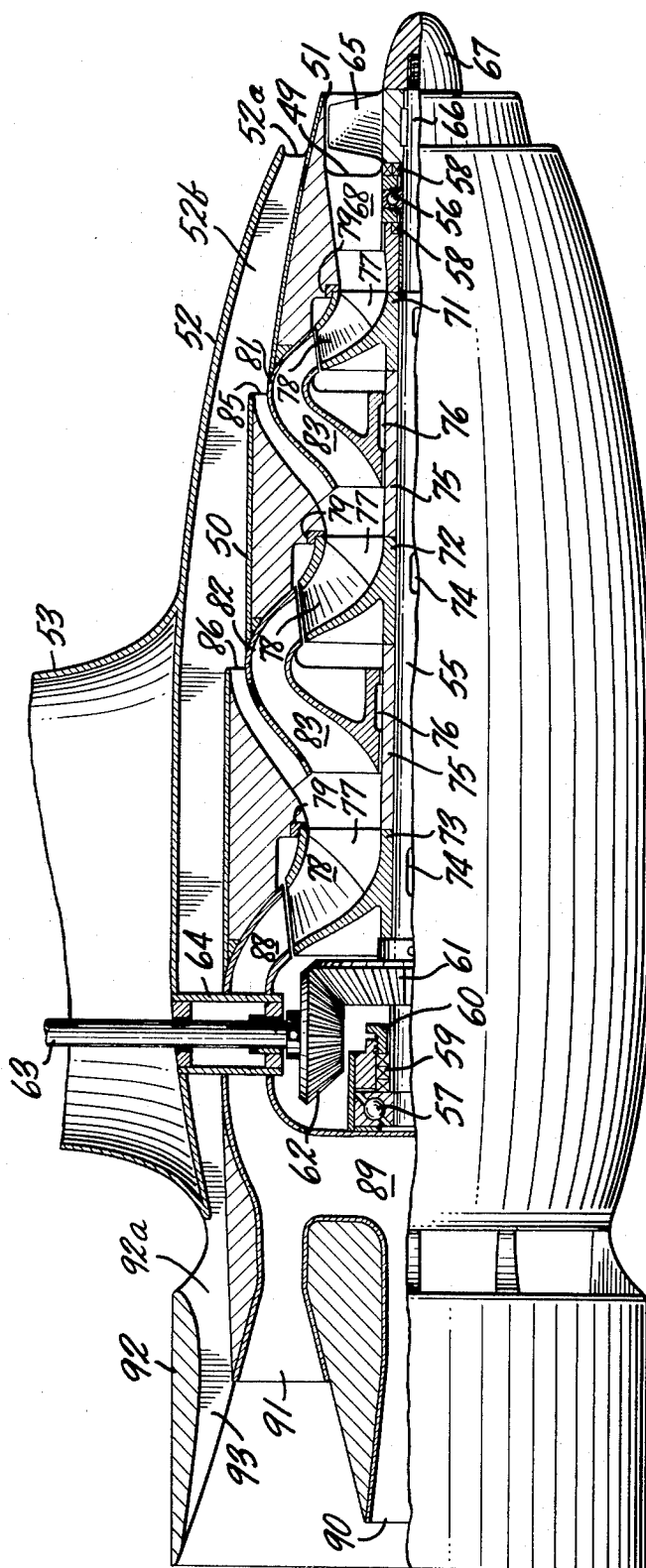


FIG. 3

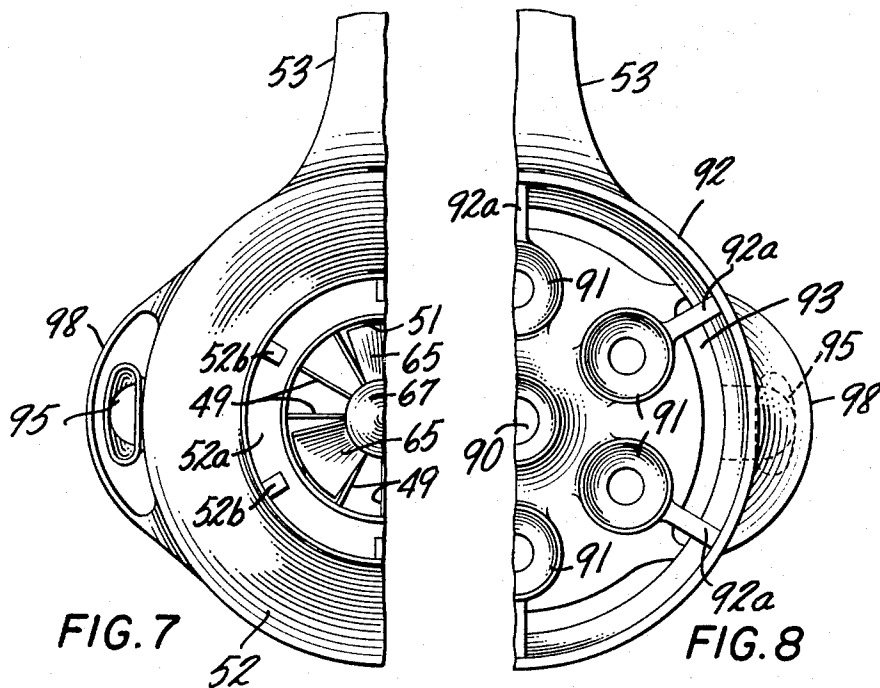
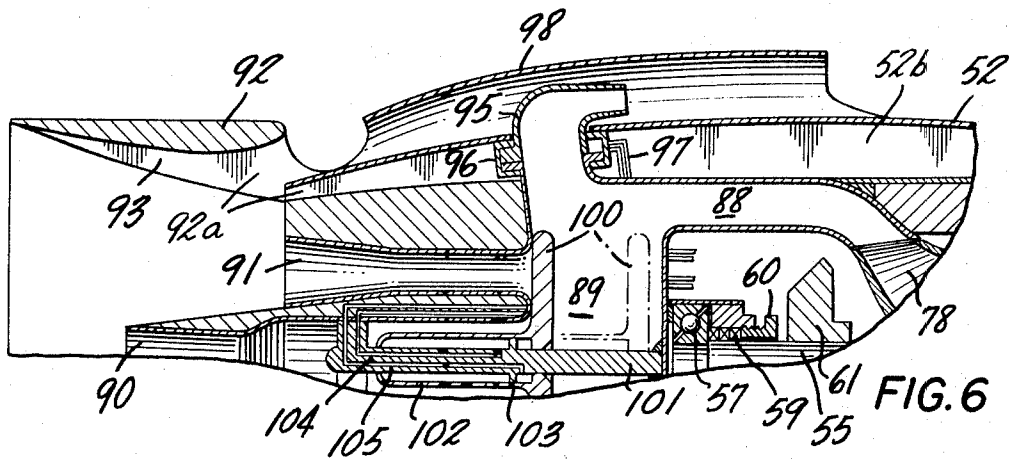


FIG. 9

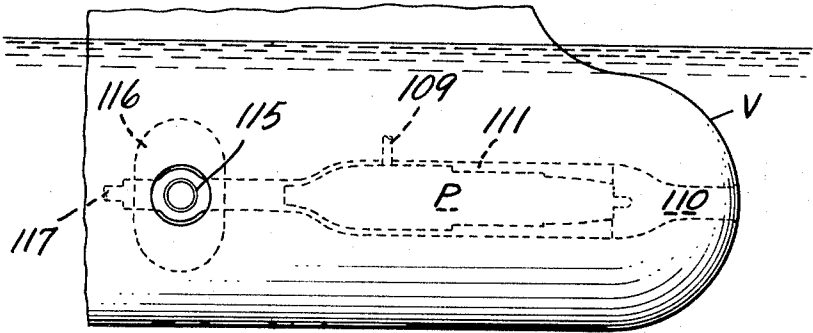
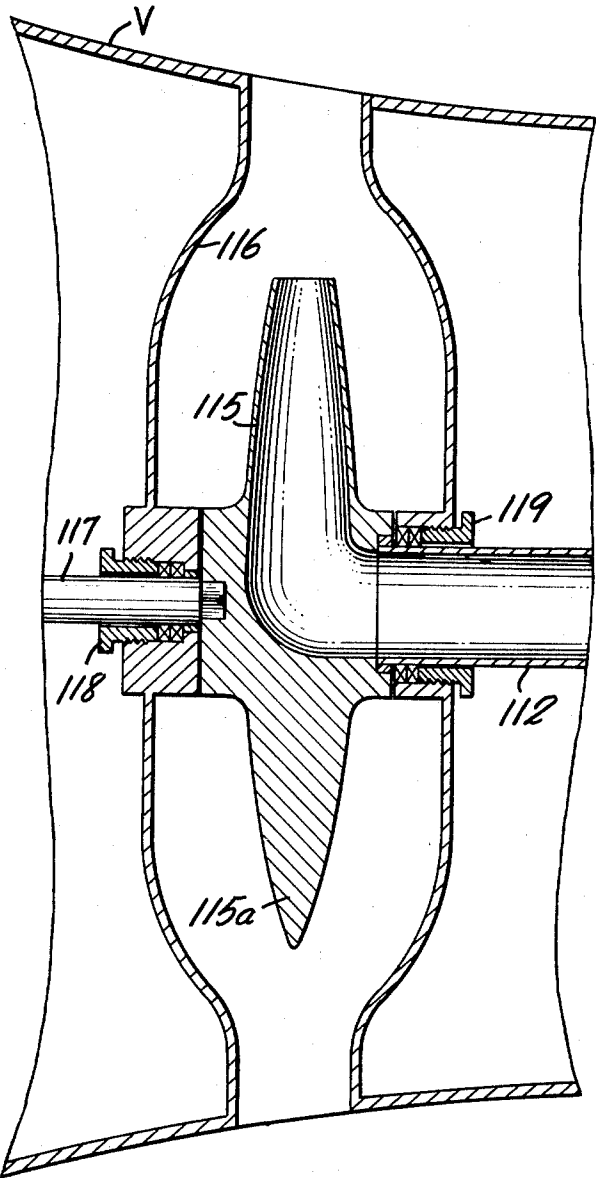


FIG. 10

SUBMERGED MULTISTAGE PUMP USABLE AS PROPULSION UNIT

The present invention relates to pumps and particularly to multi-stage submerged pumps.

It is an object of the invention to provide a multistage submerged pump of increased capacity and efficiency. A further object of the invention is to provide a submerged pump which can be used as a propulsion unit in somewhat the same manner as a jet engine on aircraft, in which case it may be provided with suitable reversing mechanisms. A further object of the invention is to provide a submerged pump which can be used as a bow thruster on a marine vessel to assist in maneuvering the vessel, for example in docking.

In accordance with the invention, a plurality of spaced impellers are fixed on a rotating shaft extending longitudinally of an elongated casing which provides a pump chamber for each impeller. The casing has an inlet at one end, an outlet at the other and passageways connecting the successive pump chambers. Additional inlets opening from the exterior of the casing into the connecting passageways between successive pump chambers admit additional fluid so that the volume as well as the velocity of the fluid is increased in its passage through the pump.

The pump in accordance with the invention can be used not only for pumping fluid from a supply to a discharge point but also as a propulsion unit, in which case the casing is streamlined and is preferably surrounded by a shroud which is spaced from the casing to provide an annular passageway between the casing and the shroud. Reversing means may be provided for directing the discharge of the pump either rearwardly or forwardly to provide propulsion alternatively in a forward or rearward direction.

The pump may also be used as a bow thruster unit installed in the bow of a ship and provided with means for directing the discharge of the pump selectively to either side so as to provide a lateral thrust on the bow of the ship.

The objects, characteristics and advantages of the invention will be more fully understood from the following description of preferred embodiments shown by way of example in the accompanying drawings in which;

FIG. 1 is a side view partially in longitudinal section of a multi-stage submerged pump in accordance with the invention;

FIG. 2 is an end view of the left-hand end of the pump as viewed in FIG. 1;

FIG. 3 is a side elevation partially in longitudinal section of a submerged multi-stage pump in accordance with the invention used as propulsion unit;

FIGS. 4 and 5 are half-end views of the inlet end and discharge end respectively of the pump shown in FIG. 3, the other half being a mirror image of the half that is shown;

FIG. 6 is a partial longitudinal section of the discharge end portion of a pump similar to that of FIG. 3 but showing reversing mechanism;

FIGS. 7 and 8 are half-end views of the inlet end and discharge end respectively of a pump provided with reversing mechanism as shown in FIG. 6, the other half being a mirror image of the half that is shown;

FIG. 9 is a partial horizontal section illustrating the use of a pump in accordance with the invention as a bow thruster of a marine vessel; and

FIG. 10 is a schematic side view illustrating a bow thruster installation.

A pump in accordance with the invention as illustrated in FIGS. 1 and 2 comprises an elongated casing 10 which is of circular cross-section and is shown as having a base portion 11. At one end, the casing is provided with a suction inlet 12 while at the opposite end there is a discharge 13. A rotatable shaft 15 extends longitudinally of the casing and projects at one end for connection to a motor, turbine or other drive means providing suitable bearings for the shaft. A fluid-type seal between the casing 10 and the shaft 15 at the end where the shaft projects is provided by a gland nut 16 applying pressure to packing rings 17 which bear on a sleeve 18 fixed on the shaft.

A plurality of impellers 21, 22, 23 and 24 spaced axially from one another by spacing sleeves 25 are secured on the shaft by an impeller nut 26 and are keyed or otherwise fixed to the shaft for example by keys or pins 19, so as to rotate therewith. Each of the impellers has an annular passageway 27 having an inlet end 27a which opens approximately axially toward the inlet end of the casing and a discharge end 27b which opens approximately radially outwardly. As viewed in axial section, the passageways 27 are generally J-shaped with a short axial portion and a longer radial portion joined by a smooth curve. The annular passageway 27 of each impeller is divided by a plurality of vanes 28 which extend radially outwardly from a point near the inlet end of the passage to the discharge end. Depending on the design characteristics of the pump, the vanes 28 may be essentially radial or may be inclined, for example spirally, in accordance with centrifugal pump design practice. The impellers are of progressively increasing size both axially and radially with the smallest impeller 21 at the inlet end of the casing and the largest impeller 24 at the discharge end.

Diffusers 35, 36 and 37 divide the casing 10 into pump chambers 31, 32, 33 and 34 which are of a size and shape to receive the impellers 21, 22, 23 and 24 respectively with sufficient clearance to provide free running of the impellers. The diffusers together with adjacent portions of the casing provide connecting passageways 38 each of which connects the discharge end 27b of the passageway 27 of a preceding impeller with the inlet 27a of a succeeding impeller. The pump chambers 31, 32, 33 and 34 are thereby connected in series with one another so that fluid drawn in through the inlet 12 passes successively through the pump chambers 31, 32, 33 and 34 and is discharged through the discharge 13. In the passage of the fluid through the pump, the velocity of the fluid is progressively increased by the successive action of impellers 21, 22, 23 and 24. Moreover, the cross-sectional area of each of the connecting passageways 38 decreases in the direction of flow of the fluid so that the velocity of the fluid is increased in passing from one pump chamber to the next.

In accordance with the invention, the diffusers 35, 36 and 37 together with adjacent portions of the casing 10 provide additional inlets 40 opening into the connecting passageways 38. The additional inlet passageways 40 are substantially annular, being interrupted by connecting portions 41 which connect adjacent portions of the casing. At the points at which the inlet passages 40 merge with the connecting passageways 38, the velocity of the fluid being pumped is sufficiently high that its pressure is lower than that of the fluid in which the pump is submerged so that additional fluid is drawn into the pump through each of the additional inlet passages 40. Moreover, the inlet passageways 40 merge into the connecting passageways 38 in such a manner as to provide an injection effect to induce flow of fluid from the inlet passageways into the pump. Hence, in the passage of fluid through the pump, both its velocity and its volume are progressively increased with resulting increases in both the capacity and the efficiency of the pump. Guide vanes 42 are provided in the connecting passageways 38 and adjacent portions of the additional inlet passageways 40 so as to direct the fluid in the most efficient manner to the next succeeding impeller. The guide vanes 42 extend in a generally radial direction but may be somewhat inclined as desired to provide optimum operating characteristics of the pump.

The discharge 13 has a progressively increasing cross-sectional area so that the velocity of the fluid discharged by the last impeller 24 is in part converted to pressure.

For convenience of assembly, the casing 10 is made in two halves which are assembled by means of flanges 43 and bolts 44 as seen in FIG. 2.

As illustrated in FIGS. 3-5, a submerged pump in accordance with the present invention can advantageously be used as a jet propulsion unit for a marine vessel. The unit shown in FIGS. 3-5 comprises an elongated streamlined casing 50 having an inlet opening 51 at its forward end. The casing 50 is shown provided with a streamlined shroud 52 which

surrounds the casing with an annular space between the casing and the shroud. The unit is mounted outboard of a vessel which it is to propel by means of a suitable support shown as a streamlined strut 53 projecting from the vessel. The casing and shroud are of circular cross-section and are generally of torpedo shape with the forward end smaller than the mid-section and rear end to reduce resistance.

A shaft 55 is rotatably supported in the casing by bearings 56 and 57. Packing rings 58 provide a water-tight seal for the bearing 56 while packing rings 59 compressed by a gland nut 60 provide a water-tight seal for the bearing 57. The shaft 55 is driven by means of a beveled gear 61 which is keyed or otherwise fixed on shaft and meshes with a beveled gear 62 fixed on a shaft 63 which extends outwardly from a power plant in the vessel through the strut 53. The driving shaft 63 is protected by a shroud 64.

A propeller 65 is fixed on the forward end of the shaft 55, for example by means of a key 66 and is secured by a nut 67 screwed onto a threaded end portion of the shaft. The propeller 65 rotates inside the inlet passage 51 at the forward end of the casing 50 and is preferably a multi-blade propeller having a diameter slightly less than the internal diameter of the inlet passage so as to provide suitable clearance. Rearwardly of the propeller the inlet passage decreases in diameter and is provided with a plurality of radial guide vanes 68 which extend in an axial direction. Rearwardly of the propeller 65, a plurality of impellers 71, 72 and 73 are secured on the shaft 55 for example by keys 74 and are spaced axially from one another by sleeves 75 secured to the casing for example by keys 76. Each of the impellers has a substantially annular fluid passageway 77 which has an inlet end opening forwardly near the shaft 55 and which extends rearwardly and radially outwardly from the inlet so as to provide a combined radial and axial flow. The flow of fluid through the passageways 77 is guided by vanes 78 which extend in a general axial and radial direction but may be inclined for example in spiral form in accordance with accepted pump designs. The impellers are of progressively increasing size, the forwardmost impeller 71 being the smallest and the rearwardmost impeller 73 being the largest so that they accelerate the increasing volume of fluid efficiently.

The casing 50 provides pump chambers for the impellers, each of the chambers being of suitable size and shape to accommodate the respective impeller. Wear rings 79 are provided in the casing at the forward end of each of the impellers. The casing further provides an annular passageway 81 connecting the discharge of impeller 71 with the inlet of impeller 72 and an annular passageway 82 connecting the discharge of impeller 72 with the inlet of impeller 73. The connecting passageways 81 and 82 curve outwardly and then inwardly to provide smooth non-turbulent flow of the fluid from one impeller to the next. The cross-sectional area of each of the connecting passageways decreases in the direction flow so as to provide for increasing velocity and correspondingly decreasing pressure of the fluid. Flow of fluid through the connecting passageways 81 and 82 is guided by circumferentially spaced vanes 83 which extend in a generally axial direction.

Additional substantially annular inlets 85 and 86 open into the connecting passageways 81 and 82 slightly in advance of the impellers 72 and 73 respectively so as to admit additional water to the pump. The inlet end of the inlet passages 85 and 86 open forwardly so as to increase the flow of water through the passageways by a ram effect. Moreover, the cross-sectional area of the annular space between the casing 50 and the shroud 52 increases toward the rear from the inlet end 52a of the shroud so that the fluid pressure inside the shroud increases so as to increase the pressure differential between the liquid in the space between the shroud and the casing and the liquid in the connecting passageways 81 and 82 at the points where the inlet passageways 85 and 86 open into them. The additional liquid entering through the passageways 85 and 86 materially increases the capacity of the pump.

Liquid from the final impeller 73 is discharged through a substantially annular discharge passageway 88 into a diffusion chamber 89 at the rear of the casing. From the diffusion chamber the liquid is discharged rearwardly through a plurality of diverging nozzles including a central nozzle 90 and a surrounding array of nozzles 91. The central nozzle 90 extends farther rearwardly than the surrounding nozzles 91. The nozzle assembly at the rear of the pump casing is surrounded by a tail ring 92 which is spaced outwardly so as to provide an annular passageway 93 between the tail ring and the rear end of the casing. Moreover, the leading edge of the tail ring 92 is spaced rearwardly from the trailing edge of the shroud 52 and is spaced radially outwardly of the trailing edge of the shroud so as to admit additional liquid to the passage 93. The flow of liquid through the passage 93 induced by the discharge from the nozzles 90, 91 augments the propulsive force provided by the unit.

In the operation of the propulsion unit shown in FIGS. 3 to 5, water is drawn into the pump through the main inlet 51. Entry of water into the pump is assisted by the propeller 65 and by a ram effect which increases as the speed of the unit through the water increases. The velocity of the water in the pump is progressively increased by the successive impellers 71, 72 and 73. Between successive impellers additional water is introduced into the pump through the auxiliary inlet passageways 85, 86. The entry of water through the auxiliary inlets is also increased by a ram effect as the speed of the unit through the water increases. With the construction shown and described, cavitation is effectively avoided.

The shroud 52 and the tail ring 92 are suitably supported with respect to the casing by longitudinally extending vanes 52b and 92a respectively.

In FIGS. 6-8, there is illustrated a modification of the propulsion unit shown in FIG. 3 in order to provide selectively either a forward or a rearward thrust. In addition to rearwardly projecting nozzles 90 and 91 which provide a forward thrust, a plurality of reversing nozzles 95 extend laterally from the diffusion chamber 89 and each is rotatable by means of a hydraulic rotator 96 so as to be directed either rearwardly or forwardly. Hydraulic fluid for operating the rotators is supplied through control lines 97. The side nozzles are protected by side shrouds 98 which are spaced outwardly from the main shroud 52 so as to provide passageways in which the nozzles 95 are located. The side shrouds 98 improve streamlining of the unit and increase the effectiveness of the nozzles 95 by a diffusing technique.

A reversing valve disc 100 is movable axially in the diffusion chamber 89 along a guide rod 101 by means of an actuating cylinder 102 fixed to the reversing disc. The guide rod 101 is provided with a piston ring 103 fitting closely in the cylinder 102 and with passageways 104 and 105 opening respectively on opposite sides of the piston ring 103. When hydraulic fluid is supplied through the passageway 104, the reversing disc 100 is moved rearwardly to the position shown in solid lines, thereby closing the rearwardly directed nozzles 90 and 91. When hydraulic fluid is supplied through the passageways 105, the reversing disc is moved forwardly to the position shown in broken lines so that the rearwardly projecting nozzles 90 and 91 are open.

To provide forward propulsion, the reversing disc 100 is moved to its forward (broken line) position and the side nozzles 95 are rotated so as to be directed rearwardly. Fluid from the diffusing chamber 89 is thereby discharged rearwardly through the nozzles 90 and 91 and also through the side nozzles 95 to provide a propulsive force in a forward direction. To provide rearward propulsion, the reversing disc 100 is moved to its rearward (solid line) position so as to close the rearwardly directed nozzles 90 and 91 and the side nozzles 95 are rotated so as to be directed forwardly as shown in FIG. 6. Hence, pressure fluid from the diffusing chamber 89 discharged forwardly through the side nozzles 95 produces a rearwardly directed thrust.

FIGS. 9 and 10 illustrate the use of a propulsion unit in accordance with the present invention as a bow thruster for a marine vessel. As illustrated schematically in FIG. 10, a pump P which may be like that shown in FIG. 3 is installed in the bow of a vessel V with its axis disposed longitudinally of the vessel. Water is admitted to the pump through an inlet passage 110 which opens forwardly in the bow of the vessel. The pump is surrounded by a substantially annular passageway 111 which admits water to the additional side inlets of the pump. The pump is driven from suitable power means through a shaft 109.

The output of the pump is conducted by a discharge tube 112 to a thruster nozzle 115 which is disposed in a passageway 116 extending transversely through the bow of the vessel and is rotatable about the axis of the discharge tube 112 so as to be directed selectively toward the port or starboard side of the vessel. The nozzle 115 is rotatable by means of a control shaft 117 which provides control by the pilot or other personnel of the vessel. Packing glands 118 and 119 provide fluid tight seals to prevent leakage of water into the interior of the vessel. A streamlining portion 115a at the rear side of the nozzle 115 is provided to improve the flow characteristics of liquid through the passageway 116.

When the bow thruster pump P is operated with the nozzle 115 in the position shown in FIG. 9, water is discharged from the nozzle 115 toward the port side of the vessel and induces additional flow of water through the passageway 116 so as to produce a thrust on the bow of the vessel tending to move it in a starboard direction. When the nozzle is rotated 180° by means of the control shaft 117 so as to be directed toward the starboard side of the vessel, operation of the pump P results in the production of a thrust toward the port side of the vessel in like manner. It will be understood that the pump and the nozzle 115 are suitably controlled from the pilot house or other convenient location on the vessel.

While preferred embodiments of the invention have been shown by way of example in the drawings and are herein specifically described, it will be understood that modifications may be made according to the requirements of particular applications of the pump. For example, if a higher discharge pressure is desired, the final stage of the pump may comprise two or more impellers operating in series without additional inlet passages between them. For each application, the number of stages and other parameters of the pump are selected in accordance with design requirements.

What I claim is:

1. A submerged propulsion unit comprising an elongated streamlined casing having forwardly facing front inlet at the forward end and a jet discharge outlet at the rearward end, a rotatable shaft extending longitudinally of said casing, a plurality of impellers fixed on said shaft and spaced axially from one another, means in said casing defining a pump chamber for each of said impellers, intermediate passageways connecting successive pump chambers with one another, an inlet passage connecting the inlet of said casing with the first of said

plurality of pump chambers and a discharge passage connecting the last of said plurality of pump chambers with said outlet of said casing, said pump casing having at least one intermediate inlet which faces forwardly of said casing and is connected with a respective intermediate passage, said impellers upon rotation by said shaft drawing fluid in through said front inlet and said intermediate inlet, impelling it rearwardly with progressively increasing velocity and discharging it from said outlet, the volume of said fluid being progressively increased by additional fluid drawn in through said intermediate inlet and said impellers increasing in size from the front toward the rear of said casing to handle said progressively increasing volume of fluid.

2. A fluid pump according to claim 1 in which said intermediate passageways are annular.

3. A fluid pump according to claim 2, in which said intermediate inlets are annular.

4. A fluid pump according to claim 2, in which each said annular intermediate passageway leads from a radially outer portion of a preceding pump chamber to a radially inner portion of a succeeding pump chamber.

5. A propulsion unit according to claim 1, comprising a shroud surrounding and spaced from said casing to define an annular passage between said shroud and casing, said intermediate inlet opening forwardly from said annular passageway into said intermediate passageway, whereby fluid is forced into said intermediate inlet by the ram effect of fluid flowing through said annular passage.

6. A propulsion unit according to claim 5, in which a tail ring surrounds and is spaced from a rear end portion of said casing to define an annular passage between said casing and said tail ring and to induce a fast-moving flow of fluid in the space between the shroud and casing to increase the ram effect on said intermediate inlet or inlets and thereby draw more water in through said intermediate inlets.

7. A propulsion unit according to claim 1, in which said outlet comprises a central rearwardly directed nozzle and a plurality of rearwardly directed nozzles arranged around said central nozzle.

8. A propulsion unit according to claim 1, in which said outlet comprises at least one rearwardly directed nozzle and at least one forwardly directed nozzle, and in which flow directing means is operable to direct discharge fluid selectively to said rearwardly directed nozzle to provide a forward propulsion force or to said rearwardly directed nozzle to provide a rearwardly propulsion force.

9. A propulsion unit according to claim 1, in which said outlet comprises a nozzle directed laterally of said pump to provide a laterally directed reaction force from the discharge of fluid from said nozzle, said nozzle being rotatable about the longitudinal axis of said pump to control the direction of said reaction force.

10. A propulsion unit according to claim 16, in which a forwardly facing annular intermediate inlet is provided opening into each of said intermediate passageways.

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