

J. F. DI STEFANO

SUBMERGED BOOSTER PUMP

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Fig. 3

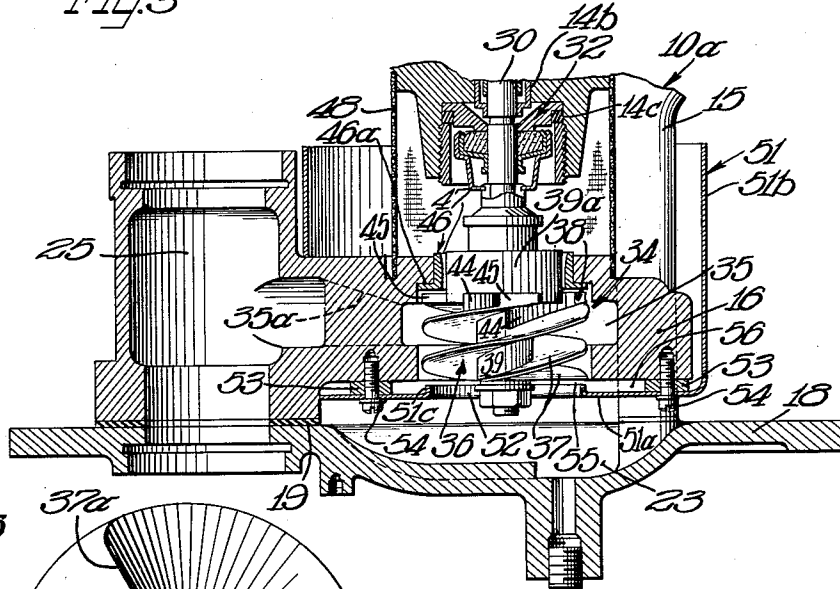


Fig. 5

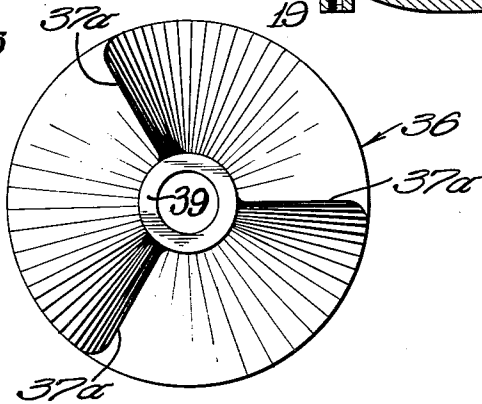


Fig. 4

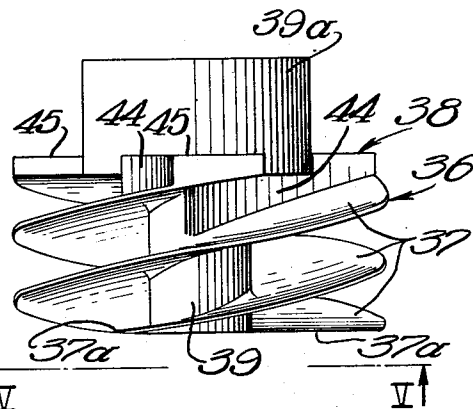
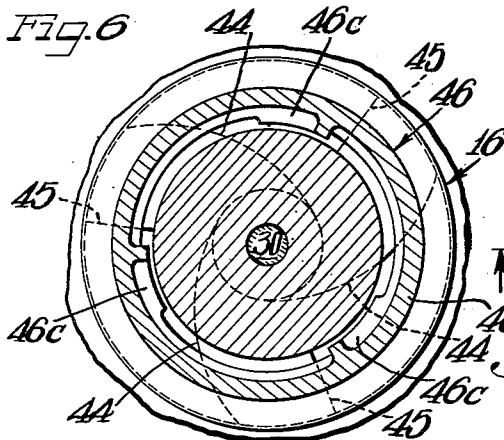


Fig. 6



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SUBMERGED BOOSTER PUMP

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5 Claims. (Cl. 103—88)

This invention relates to a submerged booster pump and more particularly to a vapor separating helicoidal type pump especially adapted for submerged mounting in a fuel cell.

Specifically, the invention deals with a submerged booster pump having an impeller equipped with a helicoidal inlet stage and a radial, or centrifugal, second stage, together with a diffusion outlet for discharge of vapors to prevent the pump from becoming gas bound.

This invention will be hereinafter described as embodied in a submerged booster pump and motor unit for aircraft fuel systems, but it should be understood that the principles of this invention are generally applicable to vapor separating pumps and the invention, therefore, is not to be limited to the preferred disclosed embodiment.

According to this invention, an electric motor and pump unit having an open ended impeller chamber surrounded by a volute is equipped with a diffusion ring in one open end and receives a two stage impeller having its inlet at the other open end. The impeller includes a multi-vane helix having a flat inlet pitch to move liquid such as fuel into the pump with very little shock effect on the liquid, thus minimizing release of vapors from the liquid at the inlet of the pump. The liquid is propelled through the helicoidal stage of the impeller and is gradually pressurized as it progresses. The second stage of the impeller includes a plurality of radial vanes blending with the vanes of the helix to subject the fuel or other fluid from the helix to centrifugal pumping action. The centrifugal pumping action of the radial blades discharges the liquid into the volute pumping chamber.

While the first or helicoidal stage of the impeller receives the liquid at the inlet of the pump at relatively low velocities and gradually raises the velocity and pressure of the liquid as it progresses along the helix until the second or radial stage of the pump builds up the pressure on the liquid and discharges the liquid at high velocities into the volute chamber, there is, nevertheless, some release of vapors from the liquid due to the movement of the liquid. These vapors, if trapped in the impeller chamber, could cause the pump to become gas bound, and therefore this invention provides a diffusion gap for removal of the vapors from the pump. The vapor diffusion feature of the invention greatly increases the altitude performance of the pump in aircraft fuel systems wherein the fuel being pumped releases bubbles of gas and vapor especially at high altitudes. The diffusion gap of the pump is provided immediately above the radial stage of the impeller and has a converging section blending into a diverging section with the restricted throat at the blending zone being at a level about one-fourth of the height of the gap path. If desired, inclined vanes can be provided in the gap to assist in the removal of vapors out of the pump. This creates a venturi effect which draws the vapor laden fluid through the diffuser and out of the pump. If desired, the helicoidal stage of the impeller can be designed with a screw displacement capacity greater than the flow delivery capacity of the pump

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to create a recirculation flow in the helix paths of the impeller. This causes movement of the vapor rich fluid from the axis to the periphery of the impeller where it can flow out of the inlet of the pump.

5 An important feature of this invention, therefore, resides in the provision of a diffusion outlet for vapors released in a helicoidal pump.

A further and important feature of the invention resides in the provision of a helicoidal pump with an open ended impeller chamber having one open end equipped with an annular diffusion gap to remove vapors from the pump.

10 An object of the invention is to provide a submerged pump and motor unit especially adapted for aircraft fuel systems wherein the pump is equipped with an open ended chamber for a multi-stage helical and radial pump impeller which coacts with one open end of the chamber to provide a vapor outlet.

A further object of the invention is to provide a helicoidal pump with a vapor diffusion gap to discharge vapors out of the pump and prevent the pump from becoming gas bound.

A still further object of the invention is to provide a pump for volatile liquids which will gradually increase the velocity of the liquid with minimum shock and will discharge vapors which are released from the liquid under the influence of the pump impeller.

15 Another object of the invention is to provide a multi-stage helicoidal and radial pump with an annular vapor release gap adjacent the radial stage.

A further object of the invention is to provide a booster pump especially adapted for aircraft fuel systems wherein the flow therethrough of volatile fuels is gently accelerated and maintained under pressure to minimize release of bubbles of gas and vapor from the fuel but wherein any such released bubbles are discharged through a diffusion chamber separate from the pumping chamber of the pump.

20 Other and further objects of the invention will be apparent to those skilled in the art from the following detailed description of the annexed sheets of drawings which, by way of preferred embodiments only, illustrate two types of pumps according to this invention.

On the drawings:

25 Figure 1 is a side elevational view, with parts broken away and shown in vertical cross section, of a booster pump assembly of this invention mounted in a tank such as a fuel cell.

Figure 2 is an enlarged fragmentary vertical cross-sectional view of the diffusion ring portion of the pump of Figure 1.

Figure 3 is a fragmentary vertical cross-sectional view of a slightly modified pump according to this invention.

Figure 4 is an enlarged side elevational view of the two stage impeller of the pump of Figures 1 and 3.

Figure 5 is an end view of the first impeller stage taken along the line V—V of Figure 4.

Figure 6 is an enlarged horizontal cross-sectional view taken along the line VI—VI of Figure 1.

As shown on the drawings:

30 The pump and motor unit 10 of Figure 1 is mounted in a fuel cell 11 in alignment with an opening 11a in the bottom wall of the cell. The unit 10 includes an electric motor 12 mounted on top of a casing or housing 13, which has a conical head portion 14 for receiving the bottom of the motor and has depending posts, such as 15, carrying an annular pump casing 16 in spaced relation beneath the conical head 14.

35 The pump casing 16 is formed with an integral up-standing discharge head 17. The bottoms of the posts, such as 15, and of the casing 16, including the head 17, terminate in flush relationship and a base plate 18 is

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positioned against the under side of the bottom wall of the fuel cell spanning the opening 11a thereof to support the entire assembly of the casing 13 and the motor 12. A gasket 19 is interposed between the base plate 18 and the casing part 16, and a second gasket 20 is interposed between the peripheral portion of the base plate 18 and the bottom wall of the fuel cell 11. A mounting ring 21 is positioned against the upper side of the bottom wall of the fuel cell around the opening 11a thereof and cap screws 22 extending through the periphery of the base plate 18 and through the bottom wall of the fuel cell are secured in the mounting ring 21 to attach the base plate rigidly to the fuel cell. Means (not shown) are also provided for securing the unit 13 to the base plate.

The base plate 18 provides a sump 23 in free open communication with the fuel in the cell 11 to receive fuel therefrom. An opening 24 is also provided in the base 18 in alignment with a passage 25 through the discharge head 17 of the pump casing 16. A cap 26 is held in seated relationship, closing this opening 24, by means of an elongated bolt 27, which extends through the cap and through the passage 25 and is threaded into the wall of a nipple 28 mounted on top of the portion 17. The upper end of the bolt is threaded into a boss portion 28a of the nipple so that a single bolt serves to hold the cap and the nipple on opposite ends of the portion 17.

The head portion 14 of the casing 13 contains a well 14a receiving a bearing 29 for the motor armature shaft 30. A pair of flame trap sleeves 31 surround the shaft 30 beneath the bearing 29 and are disposed in a passage 14b of the head 14 which connects the well 14a with a bottom well 14c receiving a seal assembly 32 therein. The seal assembly includes a stationary seal ring anchored in the well and a rotating seal ring carried on the shaft to ride against the stationary ring. The shaft 30 extends through the annular casing portion 16 and has a nut 33 threaded on the lower end thereof.

The casing portion 16 has an open ended vertical passage 34 therethrough. An enlarged intermediate portion of said passage provides a volute pumping chamber 35, from which an outlet passage 35a discharges into the passage 25.

An impeller 36 is mounted on the shaft 30 in the passage 34. This impeller includes a multi-vane helicoidal stage 37, a multi-vane radial stage 38, and a hub 39. The helicoidal stage 37 has close-running clearance relationship with a throat ring 40 extending into the lower end of the passage 34 and secured to the bottom of the pump casing 16. Said ring 40 has a circular inlet mouth 41 of slightly smaller diameter than the diameter of the helicoidal stage 37 so as to provide a lip 42 closely underlying the inlet edges of the helical vanes. The throat ring 40 also has an upstanding cylindrical portion 43 fitted into the passage 34, with its inner surface closely surrounding the helical vanes. The upper end of the cylindrical portion 43 terminates flush with the bottom wall of the volute pumping chamber 35.

The helical vanes of the first stage 36 of the pump terminate at their upper ends in the plane of the upper wall of the pumping chamber or volute 45. Three radial vanes 44 of the second or radial stage 38 of the impeller extend generally radially outward from the hub 39. Each vane 44 is at the upper terminus of a helix blade 37 and forms an end wall for the path between two adjacent helix blades.

The hub 39 has a larger diameter top portion 39a with three radially extending flat top flanges 45 each at the terminal end of a helix blade 37. The outer ends of the vanes 44 are flush with the leading edges of these flanges 45 as shown in Figure 6. The flanges 45 have arcuate ends closely adjacent the wall of the passageway 34 above the level of the pumping chamber or volute 35.

The enlarged hub portion 39a has a flat bottom face at the upper ends of the helix blades 37. This face is flush with the bottoms of the flanges 45. The side wall of this enlarged hub portion 39a is circular and projects

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freely through the central portion of the passageway 34.

A diffuser ring 46 is secured in the upper end of the passageway 34. As shown in Figure 2, this diffuser ring has an outturned flange 46a overlying the flanges 45 of the impeller section 38. An upstanding cylindrical collar portion 46b on the diffuser ring surrounds the enlarged diameter hub portion 39a of the impeller in spaced concentric relation. An annular gap 47 is thereby provided between the hub portion 39a and the diffuser ring 46. This gap converges to a restricted throat and then diverges to the top end of the gap. The restricted throat is positioned in the gap at a level of about one-fourth of the height of the gap. The convergence and divergence of the gap provides a venturi passage between the diffuser ring and the enlarged diameter hub portion. This venturi passage is preferably equipped with three or more inclined diffused ribs or vanes 46c. As shown in Figure 6, these ribs 46c are formed on the inner face of the cylindrical collar portion 46b of the diffuser ring and are inclined to diffuse rotating fluid from the impeller in an upward path through the passageway.

As indicated by the arrows in Figure 2, the gap 47 receives vapor rich fluid from the passageway 34 through the spaces between the flanges 44. The impeller acts in the nature of a centrifugal separator whereby light vapor rich fractions of the fluid being pumped tend to collect around the hub 39 of the impeller while the heavier, fully liquid material is centrifugally discharged to the outer periphery of the impeller. This vapor laden lighter fraction, as it travels upward in the impeller stage around the impeller 39, will be discharged out of the pump through the diffused gap 47 to prevent the pump from becoming gas bound. The entrance to the gap 47 is located inwardly from the periphery of the impeller but somewhat outwardly from the hub 39 at a diameter where an optimum pumping action on the vapor rich liquid will be induced by the relative motion between the liquid and the diffuser ring. The venturi effect in the gap 47 creates a low pressure zone which, coupled with the hydrodynamic lift action of the ribs 46c, induces a discharge of light vapor laden fluid through the upper end of the gap. In addition, this discharge is assisted by the pressure on the fluid in the passageway 34 caused by the pumping action of the impeller.

A cylindrical screen extends between the pump casing 16 and the head portion 14 to enclose a diffusion chamber 49 into which the annular gap 47 opens. The vapor laden or bubble rich liquid flows this screen 48 back to the interior of the fuel cell at a level spaced materially above the sump 23 from which liquid is supplied to the inlet of the pump.

As best shown in Figures 4 and 5, the two-stage impeller 36, including the helicoidal stage part 37 and the radial or centrifugal stage 38 has the tube-like hub 39 on the motor shaft 30. The helicoidal stage 37 has the three helix vanes thereof on the hub 39 with each vane having a bottom leading edge 37a lying in the same horizontal plane for close running clearance relation with the lip 42 of the throat ring. These three leading edges gently slice liquid in the inlet of the pump for gradually accelerating the liquid along the three separate helical paths between the vanes. The liquid is thus moved axially toward the radial blades 44 which centrifugally discharge the liquid into the volute or pumping chamber 35. The liquid is accelerated rapidly by the centrifugal vanes and flows around the volute 35 through the discharge outlet 35a into the passage 25 of the nipple 28. As explained above, however, the vapor rich liquid will be diffused from the hub 39 through the gap 47.

In the embodiment of Figure 1, the throat ring 40 substantially prevents discharge of fluid out of the bottom end of the pump, since this ring closely cooperates with the inlet end of the helical vanes 37 to form an effective inlet seal.

In the embodiment of Figure 3, however, the unit

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10a is not equipped with a throat ring 40, but, instead, is provided with a deflector to coact with the lower end of the pump for receiving and directing vapor laden fuel issuing from the pump inlet. In this modified pump, the helicoidal stage of the impeller has a screw displacement capacity greater than the flow delivery capacity of the pump. This effects recirculation of fluid in the helical path. This recirculation tends to force vapor laden fluid from the hub portion 39 toward the periphery of the impeller, where the relatively free running clearance between this periphery and the wall of the passageway 34 will accommodate discharge of the vapor rich fluid around the peripheral portion of the inlet to the pump. The recirculation within the helical path therefore actually forces the lighter vapor rich liquid normally hugging the axial center of the impeller to the periphery of the impeller. Since the remaining parts of the unit 10a are identical or substantially identical with the parts described in connection with Figures 1, 2, 4, 5 and 6, they have been marked with the same reference numerals.

As shown in Figure 3, the lower end portions of the helical vanes of the helicoidal stage 37 of the impeller have free running clearance with the lower end of the passage 34. A deflector cup 51 surrounding the pump casing 16 has an apertured bottom wall 51a underlying the bottom of the pump casing 16. An upstanding cylindrical wall 51b surrounds this casing and extends upwardly therefrom to a level substantially above the discharge end of the diffuser ring 46. The bottom 51a has an upstanding circular flange 51c around the aperture 52 thereof. This flange is spaced beneath the leading ends of the vanes 37 and is held in spaced relation from the pump casing by spacers 53 which are provided on mounting screws 54 threaded into the bottom of the casing 16. The upper edge of the flange 51c is spaced slightly below and inwardly of the peripheral portion of the vanes to provide a gap 55 therebetween. This gap 55 and the space 56 between the bottom of the casing and the deflector afford passage for vapor laden or bubble rich fluid from the lower end of the passageway 34. Therefore, any bubble rich liquid discharging out of the leading end of the helix stage of the pump will be deflected away from the sump 23 so as not to mix with the incoming liquid to the pump. Vapors liberated in the pump, however, are diffused through the diffusion gap 47 in the same manner described above in connection with Figure 1. The pump of Figure 3 therefore differs from the pump of Figure 1 in the provision of an overcapacity design for the helicoidal impeller stage and the provision of a gap for passage of vapor rich liquid out of the peripheral portion of the pump inlet.

From the above descriptions it will therefore be understood that the invention provides a helicoidal pump with vapor diffusion means for preventing the pump from becoming gas bound.

It will be understood that modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

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I claim as my invention:

1. A pump comprising, an impeller having a hub, a plurality of circumferentially overlapping helical screw vanes on said hub terminating at one end in coplanar relation to form flat flanges extending radially outwardly of said hub, a corresponding plurality of radial centrifugal pumping vanes between said screw vanes and forming end wall portions in the spaces between adjoining screw vanes, the outer ends of said radial centrifugal pumping vanes being flush with the leading edges of said flat flanges, and casing means forming a pumping cavity for said impeller with an inlet at the other end of said screw vanes, and a volute pumping chamber for said centrifugal vanes with an outlet through which fluid is discharged.

2. A pump as defined in claim 1, said casing means having means forming together with said hub a diffusing gap overlying said flat flanges for receiving vapor-rich fluid from the spaces between said flat flanges, whereby fully liquid fluid is pumped to said outlet by the centrifugal vanes after separating from the fluid advanced axially by said screw vanes.

3. A pump as defined in claim 1, said pumping cavity comprising a vertical passage formed in said casing means, a throat ring having an annular shoulder projecting radially into said passage and providing an entrance in the lower end of said passage thereby to form said inlet, said shoulder underlying the inlet edges of said screw vanes for minimizing leakage at the lower end of the passage.

4. A pump as defined in claim 1, said casing means having a diffuser ring positioned therein overlying said flat flanges and spaced concentrically outwardly of said hub to form together therewith a diffusing gap for receiving vapor-rich fluid from the spaces between said flat flanges, whereby fully liquid fluid is pumped by the centrifugal vanes after separating from the fluid advanced axially by said screw vanes.

5. A pump as defined in claim 4, said diffuser ring having a nozzle-shaped inner annular face with a minimum diameter at a level about one-fourth the length of the face, said hub having a cylindrical periphery in spaced relation from said inner face of said diffuser ring to form said gap as an annular venturi passage, thereby to assist in exhausting vapor-rich fluid from the spaces between said flat flanges.

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