Dec. 22, 1942. R. R. CURTIS 2,306,302

BOOSTER PUMP

Filed Aug. 14, 1941 2 Sheets-Sheet 1

Fig. 1.

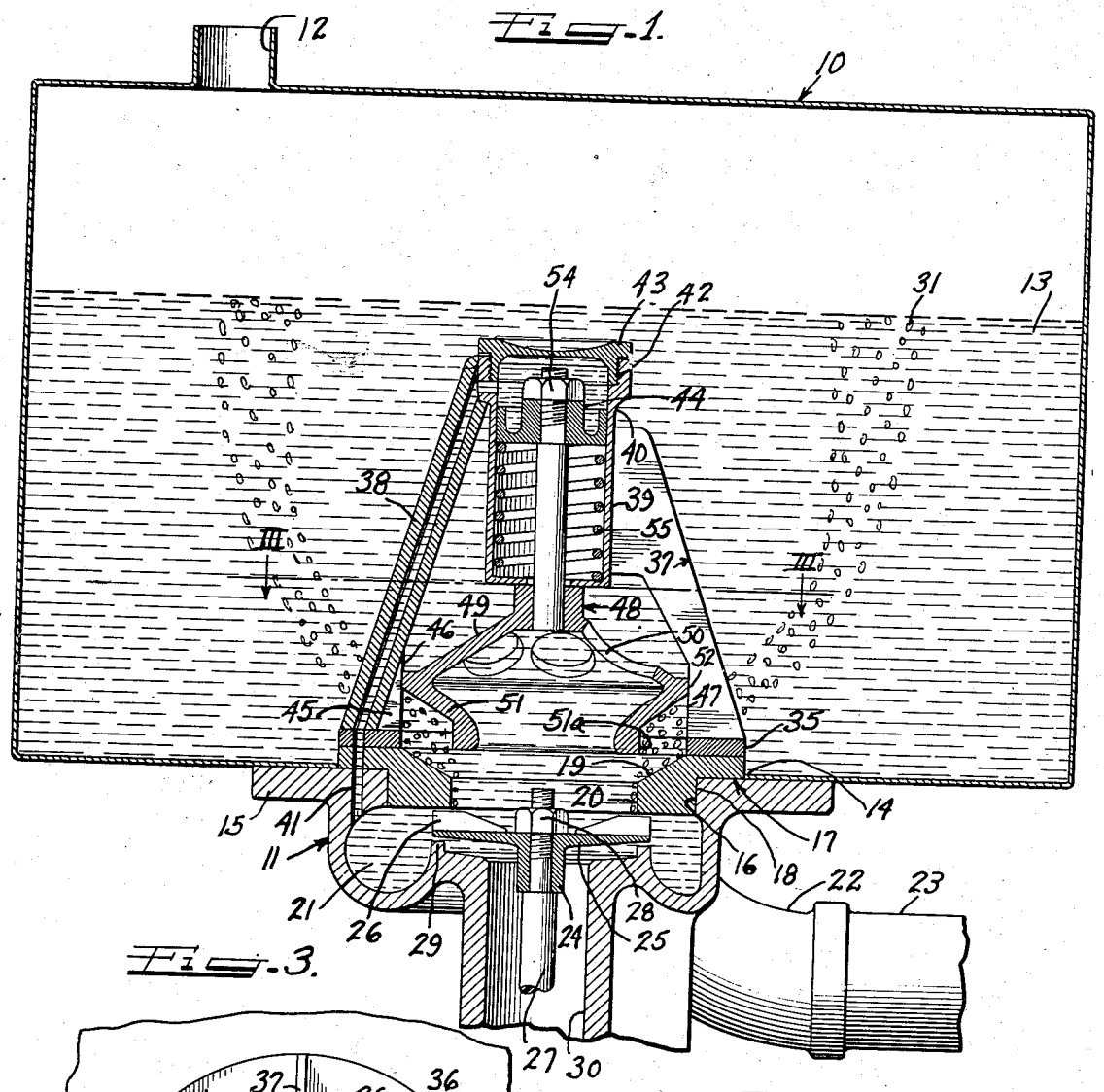


Fig. 3.

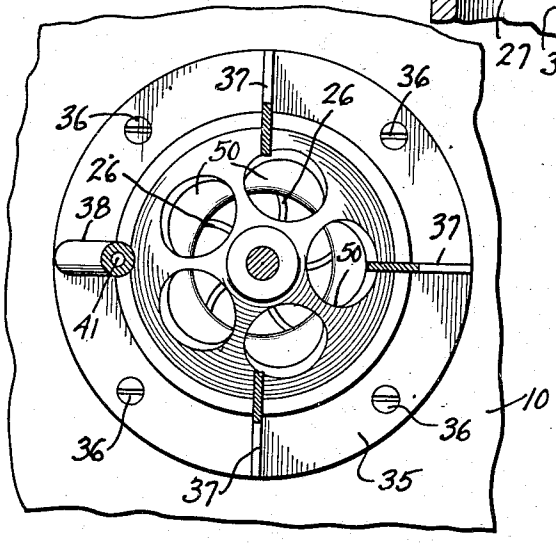
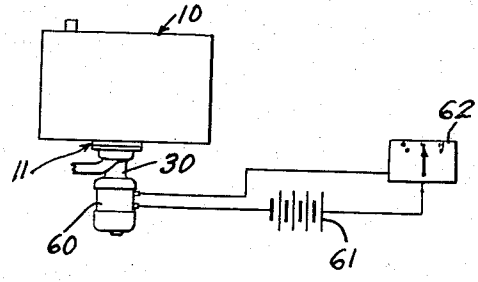


Fig. 5.



INVENTOR

RUSSELL R. CURTIS.

BY

Charles A. Fellows ATTY.

Dec. 22, 1942. R. R. CURTIS 2,306,302

BOOSTER PUMP

Filed Aug. 14, 1941 2 Sheets-Sheet 2

Fig. 2.

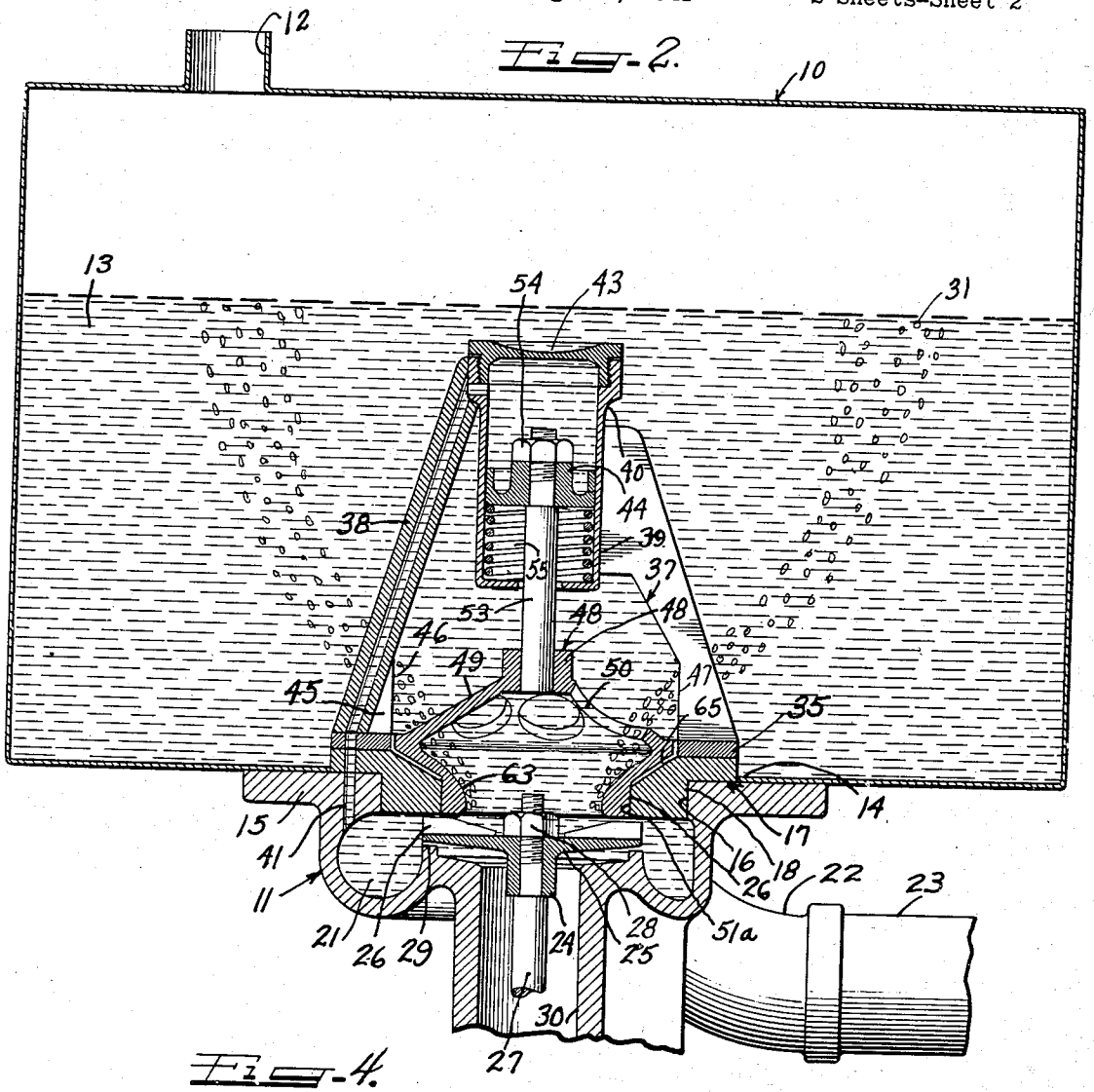


Fig. 4.

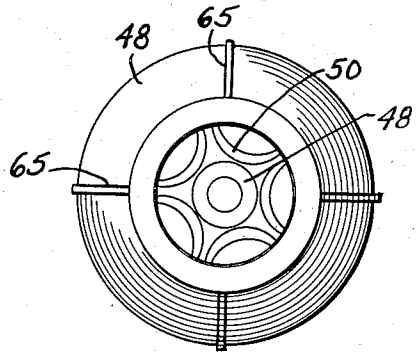
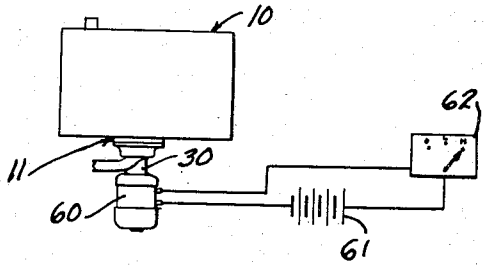


Fig. 6.



Inventor

Russell R. Curtis.

By Charles Hill Attys.

Patented Dec. 22, 1942

2,306,302

UNITED STATES PATENT OFFICE

2,306,302

BOOSTER PUMP

Russell R. Curtis, Dayton, Ohio, assignor to Curtis Pump Company, Dayton, Ohio, a corporation of Ohio

Application August 14, 1941, Serial No. 406,741

18 Claims. (Cl. 103—97)

The present invention relates to fuel systems and more particularly to a booster pump assembly in a high altitude fuel system for aircraft.

The booster pump assembly herein illustrated and to be described is preferably of the centrifugal type and is of such construction as to beat out gas and vapor bubbles from the liquid fuel to deliver fully liquid fuel from a supply source to a delivery line. When a highly volatile fuel such as used in aircraft is subjected to reduced atmospheric pressure during high altitude performance, the fuel normally breaks up and bubbles of air, other gases and fuel vapors are formed throughout the pond of fuel in the fuel tank. It has been found that agitation of the fuel from below the hydraulic gradient thereof not only increases the separation from the liquid fuel of already formed bubbles of gas and vapor but also induces additional bubble formation. These additional bubbles are formed from the dissolved or fixed gases and vapors which are liberated from the fuel by the agitation.

As a result of beating out of the liquid fuel the already formed bubbles and of the creation of additional bubbles from the previously dissolved or fixed gases and vapors in the fuel, the fuel will be more stable in high altitudes and can be made stable as the aircraft climbs and the tendency of the fuel to vaporize increases due to reduced atmospheric pressure on the fuel.

According to the present invention, the agitation capacity and pumping capacity of the pump can be varied so that the beating out of bubbles will be enhanced when the ship is climbing to high altitudes and so that the thus prepared and stabilized fuel can then be pumped in fully liquid form at higher pressures to maintain the proper engine performance at high altitude.

The present invention seeks not only to reduce the hazard of fuel system failure heretofore caused by generation and liberation of gases in the liquid fuel but also to increase the pressure of the fuel delivered to the delivery line of the system as desired to maintain high altitude engine performance.

During normal operation of the booster pump of this invention, sufficient liquid fuel is maintained at the inlet side of the engine fuel pump for maintaining constant operation of the engine. It is well known that in a centrifugal pump the discharge pressure thereof is increased by increasing the rotating speed of the impeller. If the impeller blades are only partially covered along their lengths, then the discharge pressure may also be increased by providing for additional coverage of the impeller blades. The open-ended channels defined by the impeller blades and the adjacent pump structure are thereby increased in length and an increase in discharge pressure results from higher efficiency.

This condition is effected in the present invention by providing a variable speed driving means for the impeller to increase the delivery pressure of the fuel. The increased pressure of the fuel then automatically operates a member to restrict the inlet throat opening and thereby provide greater coverage for the impeller blades to additionally increase the delivery pressure. The delivery pressure is thereby increased above the pressure that would normally result from an increase in impeller speed only.

Manual operation by the pilot to effect this change in pressure permits its use for emergency duty brought about by partial or complete failure in operation of the engine fuel pump or when delivery pressures are required above that necessary for normal operation.

It is, therefore, an object of this invention to provide a booster pump for a fuel system that insures the delivery of liquid fuel to an engine under a wide variety of operating conditions.

Another object of the present invention is the provision of a booster pump for a fuel system which is operable for discharging fuel therefrom at pressures greater than developed by variations only in the speed at which the pump is operated.

A further object of the present invention is the provision of a booster pump for a fuel system having driving means therefor whose speed is controlled as desired.

A still further object of the present invention is the provision of a booster pump for a fuel system which is operable for discharging fuel therefrom at pressures greater than developed by variations only in the speed at which the pump is operated.

Another and still further object of the present invention is the provision of a variable speed booster pump assembly in which the discharge pressures of fuel delivered by the pump change at a greater rate than the changes in the speed at which the pump is operated.

A still further object of this invention is to provide a movable throat assembly for a centrifugal pump which is automatically controlled by discharge pressure of the pump.

The novel features believed to be characteristic of the present invention are set forth with particularity in the appended claims. The inven-

tion itself, however, both as to its organization and manner of construction, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a fragmentary view in vertical cross section, with parts in elevation, of a portion of a fuel system embodying principles of the present invention and illustrating the operative relation of parts thereof under certain conditions;

Figure 2 is a view similar to Figure 1 illustrating the operative relation of parts thereof under certain other conditions;

Figure 3 is an enlarged fragmentary transverse cross-sectional view, with parts in elevation, as seen when taken substantially in the plane indicated by the line III—III of Figure 1;

Figure 4 is a bottom view in elevation of the movable throat member of the booster pump shown in Figure 2 and illustrating a modification of construction over the form shown in Figure 1; and

Figures 5 and 6 are diagrammatic views illustrating the construction by which the speed of the booster pump of this invention may be varied.

The portion of the fuel system illustrated in Figures 1 and 2 generally comprises a fuel tank 10 and a booster pump assembly 11, preferably but not necessarily, mounted on the bottom wall of the tank.

The fuel tank 10 has a vent member 12 positioned above the surface of a pond of liquid fuel 13 carried within the tank. This vent member is illustrated as being provided in the top wall of the tank although it obviously can be positioned at any point on the tank provided it is always above the surface of the pond of fuel in the tank. The fuel tank also has an outlet opening 14 which is always below the hydraulic gradient of the fuel therein and is preferably in the bottom wall of the tank.

The casing 15 of the pump 11 is connected to the bottom wall of the fuel tank by any suitable means (not shown) in such a manner that an inner shoulder 16 of the casing positions a throat ring 17 to receive fuel through the outlet opening 14.

The throat member 17 has a reduced cylindrical portion 18 seated against the shoulder 16 of the pump casing and the throat member is so shaped as to provide a tapered mouth 19 and a substantially cylindrical bore or passageway 20 below the mouth. An internal volute chamber 21 in the pump casing below the throat member 17 opens into a discharge member 22 which in turn is connected to a fuel delivery line 23 to the main fuel pump (not shown).

The pump impeller comprises a hub 24, a flange 25 and a series of curved vanes 26 connected to the flange. The impeller is secured to a driving shaft 27 by a key (not shown) and a nut 28.

The outer periphery of the impeller, defined by the ends of the vanes 26, is positioned between the throat member 17 and an annular flange portion 29 on the inside of the pump casing 15 in order that the fuel flowing into the pump will be delivered under pressure through the volute chamber 21 into the delivery line 23. A casing portion 30 houses the driving shaft 27 and is connected to a source of motive power for driving the impeller, such as an electric motor of a type which will be described further hereinafter.

As the liquid fuel 13 flows through the throat openings 19 and 20 the revolving vanes 26 create a whirlpool action therein. The portions of the vanes 26 underlying the throat members effect a radial pumping of the liquid fuel to deliver it under pressure to the pump outlet while the vane portions within the throat opening defined by the cylindrical surface 20 effect an agitation of the gas-fuel mixture flowing into the throat. These curved vane portions, lying within the throat, cause a whirlpool action which is funnel-shaped and the agitated fuel is whirled in a cork-screw path upwardly and outwardly from the vanes. This constant beating of the fuel effects an increased generation of gas and vapor bubbles over that which normally results from decreased atmospheric pressure only. The bubbles are carried outwardly and upwardly by the liquid stream flowing in a cork-screw path leaving only fully liquid fuel at the axis of the throat to be pumped by the vanes into the outlet.

When the aircraft is operated at low altitudes, the liquid fuel is in a substantially fully liquid state and the pump impeller merely delivers the fuel under pressure into the delivery line. However, as the altitude range of the aircraft is increased a point is eventually reached in which the reduced atmospheric pressure results in a generation and liberation of air, other fixed gases or vapors from the liquid fuel in the tank. This condition is aggravated as the altitude is increased.

When the fuel in the tank starts breaking up, scattered bubbles 31 will appear in the pond of fuel throughout the tank. As soon as the fuel and the gas is subjected to the action of centrifugal force by rotation of the curved impeller blades 26, the bubbles rapidly separate from the liquid fuel and are thrown out to and concentrate around the periphery of the cylindrical surface 20 in the booster pump throat from where they rise and move upwardly through the fuel in the cork-screw path in the tank along a path substantially parallel with the tapered throat surface 19. As shown in Figures 1 and 2, the bubble path gradually curves upward as the velocity of the liquid flowing in the corkscrew path decreases. The bubbles finally reach the top surface of the fuel where they escape from the top of the fuel pond into the atmosphere. This curved path is at a sufficient distance outwardly from the axis of the pump assembly so that substantially fully liquid fuel only is drawn downwardly through the axis of the whirlpool into the booster pump. When the bubbles 31 rise to the surface of the fuel pond, they break into the atmosphere above the fuel and consequently are not drawn back into the downward flowing whirlpool of fully liquified fuel entering the booster pump.

In this manner fully liquid fuel is delivered by centrifugal action of the pump to the delivery line 23 and assures the proper volume of fuel into the suction side of a fuel pump for delivery thereby directly into the aircraft engine.

The booster pump construction so far described is of the type disclosed in my co-pending application entitled "Booster pump for aircraft fuel systems," Serial No. 352,064, filed August 10, 1940. This booster pump construction is operated at a speed in which the pressure generated by the impeller is usually less than six pounds per square inch, which pressure is sufficient for assuring the flow of a proper volume of fuel into the suction side of a fuel pump even though the aircraft be operated at high altitudes

However, when the aircraft is to be operated under conditions requiring higher delivery pressures or for emergency duty through partial or total failure of the engine fuel pump or the like, the increase in discharge pressure from the pump may be obtained by operating the pump impeller at higher speeds. It has been found that discharge pressures greater than ten pounds per square inch are required for such an emergency duty.

The structure now to be described effects a discharge pressure which is greater than the pressure resulting from an increase in impeller speed only.

As best shown in Figures 1 and 3, a ring member 35, having an inner diameter substantially the same as the diameter at the widest end of the tapered throat surface 19, is connected to the throat member 17 by means of flat head screws 36 or the like.

A plurality of flat elongate support members or columns 37 are circumferentially spaced around and have their lower ends connected to the ring member 35 by any such suitable means as brazing, soldering or the like. A tubular support member and duct 38 also extends upwardly from and is connected to the ring 35 in a manner similar to the supports 37. While the support members 37 are illustrated as being three in number with only one duct support member 38 and each spaced 90° apart, it is to be understood that this number and spacing can be varied as desired, it only being necessary that sufficient space be provided therebetween to permit liquid fuel 13 to flow freely into the booster pump throat.

The upper ends of the support members 37 each have an elongated substantially vertical edge 39 to which is connected, by brazing, solder or other means, a piston cylinder 40. It is to be noted that the tubular support member 38 extends upwardly into connection with the top portion of the piston cylinder 40.

A conduit 41 for fluid flow is provided through the pump casing 15, the throat member 17, the ring 35, the tubular support member 38 and the upper portion of the cylinder 40 to hydraulically connect the piston cylinder 40 and the discharge volute 21.

The upper end of the cylinder 40 is internally threaded as at 42 for receiving therein an externally threaded end closure member 43. A piston 44 is slidably mounted in the cylinder 40 for a purpose now to be described.

It is to be noted that a flat triangular member 45 is included between the ring member 35 and the tubular support member 38 with its outer edge 46 being substantially vertical. Similarly, the lower inner edge 47 of each of the support members 37 is substantially vertical and of approximately the same length as the edge 46 on the triangular member 45. These edges act as guiding means or tracks for a movable throat member 48.

The upper portion 49 of the movable throat member 48 is substantially conical in shape with its sloping side walls having a plurality of openings 50 therethrough. These openings permit flow of liquid fuel 13 into the booster pump throat. The sidewalls of the lower portion of the movable throat member 48 slope inwardly toward the axis thereof with the inner peripheral surface being curved and the outer surface shaped to conform to the tapered surface 19 and the cylindrical surface 20 on the stationary throat member 17.

The peripheral surface 52 on the movable throat member between its upper and lower portions slidingly seats against the vertical guiding surfaces 46 and 47. The movable throat member is thereby guided for movement toward and away from the stationary throat 17.

A shaft 53, connected at one end to the movable throat member 48, extends upwardly through the bottom wall of the piston cylinder 40 and its other end is connected to the piston 44 by means of a nut 54.

A coil spring 55 is seated within the piston cylinder 40 between the bottom wall thereof and the piston 44 for maintaining the piston and the movable throat member in their uppermost positions.

As explained above, during normal operation of an aircraft, the discharge pressure of the booster pump is six pounds per square inch or less. As shown in Figure 1, this pressure is exerted through the flow conduit 41 against the upped side of the piston 44. The coil spring 55 is of a size sufficient to exert a pressure of more than six but less than ten pounds per square inch against the piston 44. Consequently, the movable throat member 48 is maintained in its uppermost position or spaced from the stationary throat 17 as long as the discharge pressure in the booster pump remains below the pressure of the coil spring.

As also shown in Figure 1, the movable throat member 48, when spaced from the stationary throat 17, acts as a deflector for the bubbles 31 as they rise from within the throat 17.

As shown in Figure 5, an electric motor 60 is carried by the shaft housing 30 and is connected to the shaft 27 for rotation of the pump impeller. The electric motor 60 is energized by a source of electrical energy 61 and the degree of energization is controlled by a rheostat member 62. The rheostat 62 is diagrammatically illustrated in Figure 5 as being provided with three settings, one of which is an off position in which the motor 60 is de-energized, an intermediate or low position in which the electric motor is energized at a speed sufficient for maintaining a discharge pressure of approximately six pounds per square inch, and a third or high position in which the speed of the electric motor is increased whereby the discharge pressure in the booster pump is raised above ten pounds per square inch.

The rheostat 62 in Figure 5 is illustrated as being in the intermediate position in which the electric motor is energized for a speed sufficient to maintain the discharge pressure at approximately six pounds per square inch. The booster pump parts are then positioned as shown in Figure 1.

Figure 6 illustrates the rheostat 62 as being in a high position in which the electric motor 60 is energized for higher speeds and the discharge pressure in the volute 21 is then raised above ten pounds per square inch. This pressure is sufficient, as exerted through the conduit 41, to force the piston 44 downwardly whereby the movable throat member 48 has moved into seated engagement on the stationary throat member 17. As the curved inlet throat 63 on the inside of the movable throat member 48 is smaller in diameter than the cylindrical surface 20 on the throat member 17, a greater coverage of the length of each of the vanes 26 is effected. This greater coverage effects a more positive centrifugal action of the pump impeller and results in a further rise

in discharge pressure necessary for emergency duty. As long as the discharge pressure is maintained above the compression pressure of the spring 55, the piston 44 will hold the movable throat member 48 in the position as illustrated in Figure 2. When the motor speed is again reduced by throwing the rheostat to its intermediate or low position, the discharge pressure in the pump will be reduced below ten pounds per square inch and the coil spring 55 will raise the piston 44 and the movable throat member 48 to their uppermost positions as illustrated in Figure 1.

Separation of the gas bubbles 31 from liquid fuel when the parts are positioned as illustrated in Figure 2, is the same as that illustrated and described in Figure 1 with the exception that no deflector member will aid in deflecting the bubbles further outward from the downwardly flowing whirlpool. However, the whirlpool action in the fuel in the throat opening caused by rotation of the impeller blades will urge the bubbles angularly outward from the axis of the booster pump and will permit fully liquid fuel within the portion of the pump between the support members to be drawn downwardly through the restricted throat opening.

The cooperating cylindrical surfaces on the two throat members effects a seal therebetween so that flow of fuel is entirely through the throat opening 63 when the throat members are positioned as illustrated in Figure 2. However, should it be found that a film of fuel between the adjacent tapered surfaces on the throat members obstructs full seating therebetween, then a modified arrangement as illustrated in Figure 4 may be provided on the tapered seat of the movable member 48. A plurality of radially extending ribs 65 may be provided on the tapered under surface of the movable throat whereby the ribs will solidly seat on the tapered surface 19 of the stationary throat member 17. Flow between the thus seated ribbed throat and the stationary throat will then be prevented by the full seat seal between the cylindrical surface 20 of the stationary throat 17 and the complemental cylindrical wall 51a of the movable throat 48.

It will be apparent from the foregoing that I have provided a variable speed and pressure booster pump assembly for separating gas and liquid fuel in a fuel system for aircraft. Furthermore, the arrangement in this invention provides for an increase in discharge pressure of the pump greater than is effected only by a change in speed of the pump impeller.

While particular embodiments only of this invention have been illustrated, it will, of course, be understood that the invention should not be limited thereto, since many modifications may be made and, therefore, it is contemplated by the appended claims to cover all such modifications as fall within the true spirit and scope of the present invention.

I claim as my invention:

1. In a pump assembly having an inlet throat and a discharge outlet, the improvements comprising a throat member normally spaced from and having an inlet opening smaller than said first inlet throat, said throat members being arranged for seated engagement and one of the throat members being mounted for movement toward and away from the other, and means sensitive to the discharge pressure in said pump for so moving said one throat member.

2. In a pump assembly having an inlet throat and a discharge outlet, the improvements comprising a second inlet throat engageable with and having a flow opening therethrough of smaller diameter than said first inlet throat, said inlet throats being normally spaced to permit flow of liquid into said pump through said first inlet throat, and piston means operable at a predetermined discharge pressure in said pump for moving one of said inlet throats into engagement with the other throat whereby the flow of liquid into the pump is through said second inlet throat.

3. In a pump assembly having an inlet throat and a discharge outlet, the improvements comprising a second inlet throat having an opening therein smaller than said first inlet throat, pressure means normally maintaining said throats in spaced relation permitting flow of liquid into the pump through said first inlet throat, and means controlled by the discharge pressure in said pump for urging one of said throats into engagement with the other throat when said discharge pressure exceeds the pressure of said means whereby the flow of liquid into said pump is through said second inlet throat.

4. In a pump assembly having an inlet throat and a discharge outlet, the improvements comprising a second inlet throat having an opening therein smaller than said first inlet throat, spring means normally maintaining said throats in spaced relation whereby liquid flows into said pump through said first inlet throat, and means operable by the discharge pressure of said pump and in opposition to said spring means for urging one of said throats into engagement with the other throat whereby liquid flows into said pump through said second inlet throat.

5. In a pump assembly having an inlet throat, an impeller having blades with portions longitudinally overlapped by said inlet throat, and movable means concentric with said throat for increasing the longitudinally overlapped relation of said inlet throat and said blades for increasing the discharge pressure of liquid pumped by the blades.

6. In a pump assembly having an inlet throat, an impeller adjacent said inlet throat and having vane blades overlapped by the periphery of the throat opening, a hollow member movable into and out of said throat opening for increasing the overlapping of the vane blades whereby the discharge pressure of liquid pumped by the blades is increased, and means for so moving said hollow member.

7. In a pump assembly having an inlet throat, an impeller adjacent said inlet throat and having vane blades overlapped by the periphery of the throat opening, a second inlet throat sized for seating on and extending into said first inlet throat to restrict the throat opening into the pump and increase the overlapping of the vane blades to thereby increase the discharge pressure of liquid pumped by the blades, and means controlled by the discharge pressure of said pump for moving one of said throats toward and away from the other throat.

8. A centrifugal booster pump assembly comprising an inlet throat, an impeller for agitating liquid flowing into said throat for separating gaseous bubbles therefrom, a discharge outlet, a second inlet throat movable toward and away from said first inlet throat, said second inlet throat having a smaller liquid flow opening therein than said first inlet throat, pressure means normally maintaining said throats in spaced relation whereby said second throat deflects in an outward direction the gaseous bubbles rising from

said first throat and gas-free liquid flows through said first throat, piston means, and a conduit connecting said pump discharge and said piston means whereby said second throat is moved into engagement with said first throat when the discharge pressure exceeds that of the pressure means for restricting the size of the liquid flow opening into said pump.

9. A centrifugal booster pump for a fuel system for separating gas from a gas-liquid mixture, comprising a casing defining a discharge volute, an inlet and an outlet for said volute, a tapered throat in said inlet, an impeller for agitating gas-liquid mixture flowing through said throat for separating gas therefrom and delivering the gas free liquid under pressure to said outlet, spaced support columns extending upwardly from said tapered throat, a piston chamber carried by said columns, a piston in said chamber, a second tapered throat connected to said piston and movable therewith toward and away from said first tapered throat, said second tapered throat having a flow opening therethrough smaller than said first throat, pressure means on one side of said piston for normally maintaining said throat members in spaced relation, and conduit means connecting the other side of said piston and said discharge volute whereby the discharge pressure in said pump maintains said throat members in engagement when the discharge pressure exceeds that of said pressure means.

10. A centrifugal booster pump for a fuel system for separating gas from a gas-liquid mixture, comprising a casing defining a discharge volute, an inlet and an outlet for said volute, a stationary throat member in said inlet, an impeller adjacent said throat member and having vane blades overlapped by the periphery of the throat opening in said member, said impeller agitating gas-liquid mixture flowing through said throat member for separating gas therefrom and delivering the gas-free liquid under pressure to said outlet, support columns on said throat member, a movable throat member sized for seating on and extending into said stationary inlet throat to restrict the throat opening into the pump and increase the overlapping of the vane blades to thereby increase the discharge pressure of liquid pumped by the blades, guide means on said columns for guiding said movable throat member, piston means for moving said movable guided throat member toward and away from said stationary throat member, and conduit means hydraulically connecting said discharge volute and said piston means whereby the movement of said movable throat member is controlled by the discharge pressure in said volute.

11. A centrifugal booster pump for a fuel system for separating gas from a gas-liquid mixture, comprising a casing defining a discharge volute, an inlet and an outlet for said volute, a rotatable impeller adjacent said inlet, relatively movable throat members in said inlet overlapping the periphery of said impeller, each of said throat members defining a different size inlet opening for varying the overlapping of said impeller to thereby change the discharge pressure of said pump, a piston cylinder, a piston in said cylinder, conduit means connecting said discharge volute and one end of said piston cylinder, and a coil spring between the other end of said piston cylinder and said piston for normally maintaining said throat members in spaced relation, said piston moving and maintaining said throat members together when the discharge pressure in the pump is greater than the pressure of said coil spring.

12. A liquid pump assembly comprising relatively movable hollow throat members movable into and out of telescopic engagement with each other to vary the size of the inlet opening into the pump, a rotatable impeller having blades overlapped by the inlet opening of the pump defined by one of the throat members, and means controlled by the changes in discharge pressure of said pump for relatively moving said throat members into and out of said telescopic engagement.

13. A liquid pump assembly comprising a throat member defining an inlet opening to the pump, a second throat member movable toward and away from said first throat member for defining a different size inlet opening to the pump, an impeller overlapped by said throat members, means for driving said impeller, a multi-speed control device for said driving means, and means controlled by the discharge pressure of said pump for moving said second throat member, said throat members being spaced when the discharge pressure of said pump is below a predetermined value and being maintained in engagement for decreasing the size of the inlet opening to the pump and increasing the overlapping of said impeller when the discharge pressure exceeds said predetermined value.

14. A liquid pump assembly comprising a throat member defining an inlet opening to the pump, a second throat member movable toward and away from said first throat member for defining a different size inlet opening to the pump, an impeller overlapped by said throat members, an electric motor for driving said impeller, an electrical supply source for energizing and de-energizing said motor, rheostat means for varying the speed of the motor, and means controlled by the discharge pressure of said pump for moving said second throat member, said throat members being spaced when the discharge pressure of said pump is below a predetermined value and being moved into and maintained in engagement for decreasing the size of the inlet opening to the pump and increasing the overlapping of said impeller when the discharge pressure exceeds said predetermined value.

15. In a centrifugal pump assembly including an impeller, a suction inlet, and a passageway adjacent said inlet receiving the impeller, the improvement which comprises a device for changing the size of said inlet and thereby changing the length of said passageway.

16. In a pump assembly having a housing defining an inlet and an outlet, a rotatable impeller between said inlet and said outlet having vanes thereon defining with said housing substantially open-ended pumping channels, and movable means for restricting the size of said inlet and increasing the length of said channels to enhance the pumping capacity of said pump.

17. A liquid pump assembly comprising a throat ring defining an inlet opening to the pump, a second throat ring movable toward and away from said first throat ring for defining a different size inlet opening to the pump, a rotatable impeller overlapped by said throat rings, and control means sensitive to variations in the discharge pressure of the pump for controlling the relative movement of said throat rings, said control means including pressure exerting means for maintaining said second throat ring away

from said first throat ring when the discharge pressure of the pump is less than the pressure exerted by said last means, said control means being effective for moving and maintaining said second throat ring in engagement with said first throat ring when the discharge pressure of said pump exceeds the pressure exerted by said last means.

18. In a pump assembly having an inlet, an impeller with agitating vanes uncovered along their lengths and exposed to the inlet together with pumping vanes covered along their lengths to define walls of pumping channels for receiving material to be pumped from the agitating vanes, and means for simultaneously increasing the covered lengths of said pumping vanes while decreasing the uncovered lengths of the agitating vanes to thereby increase the effective lengths of the pumping channels.

RUSSELL R. CURTIS.