

March 14, 1950

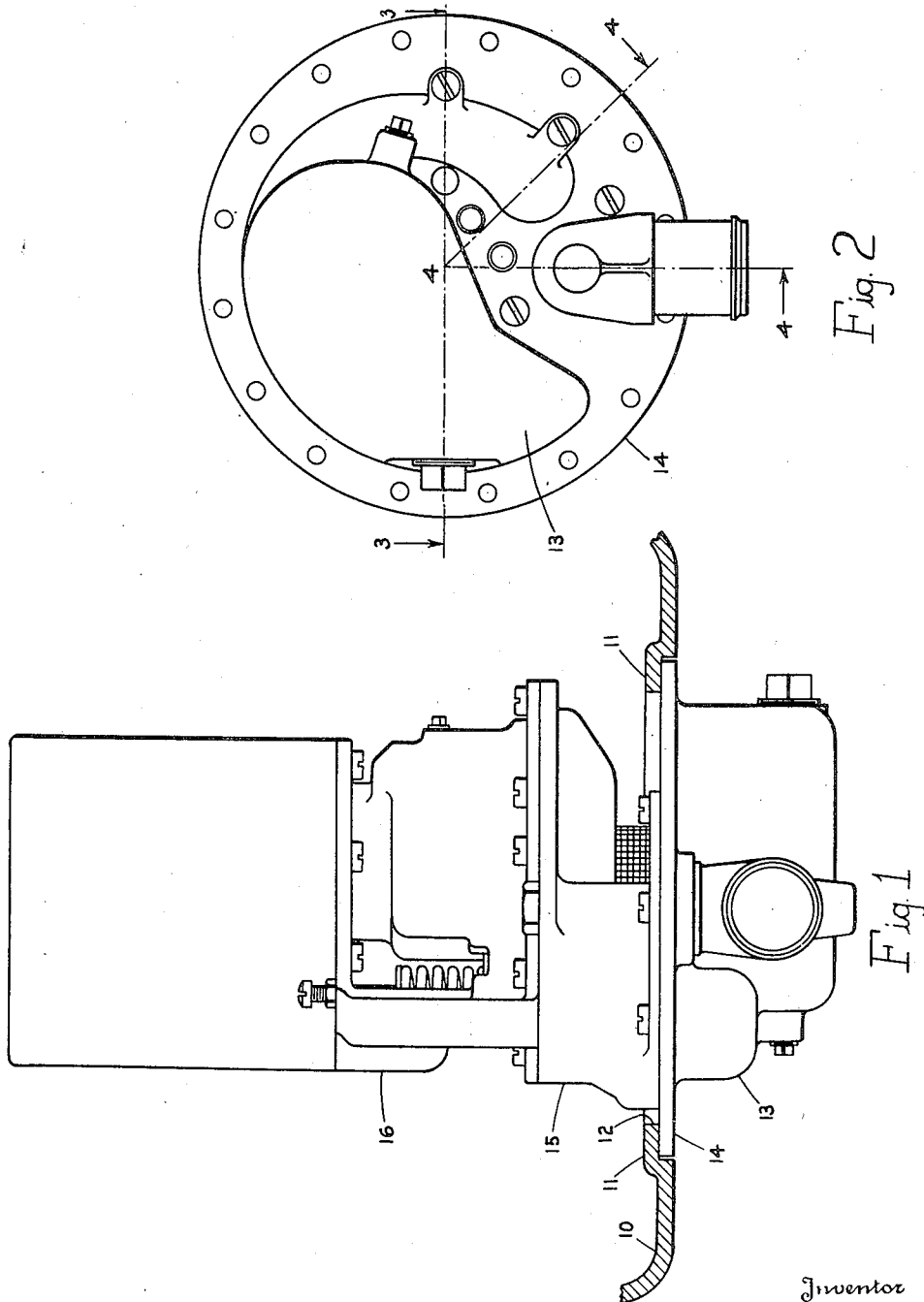
H. E. ADAMS

2,500,228

PUMP ASSEMBLY

Original Filed Sept. 19, 1945

3 Sheets-Sheet 1



Inventor

Harold E. Adams

By *Moses, Nolte, Crews + Berry*

Attorneys

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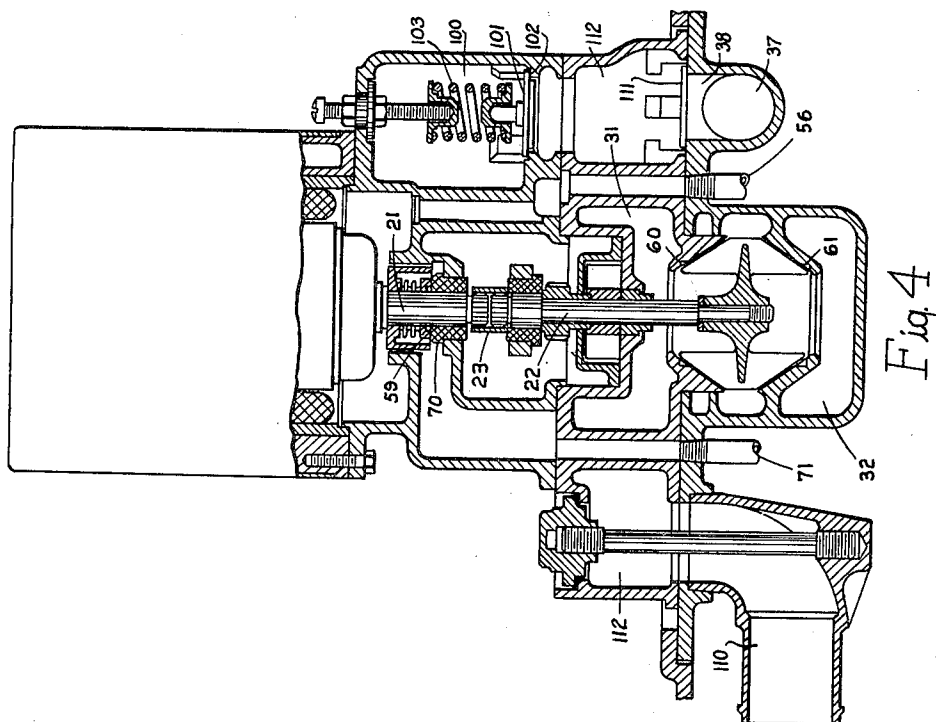
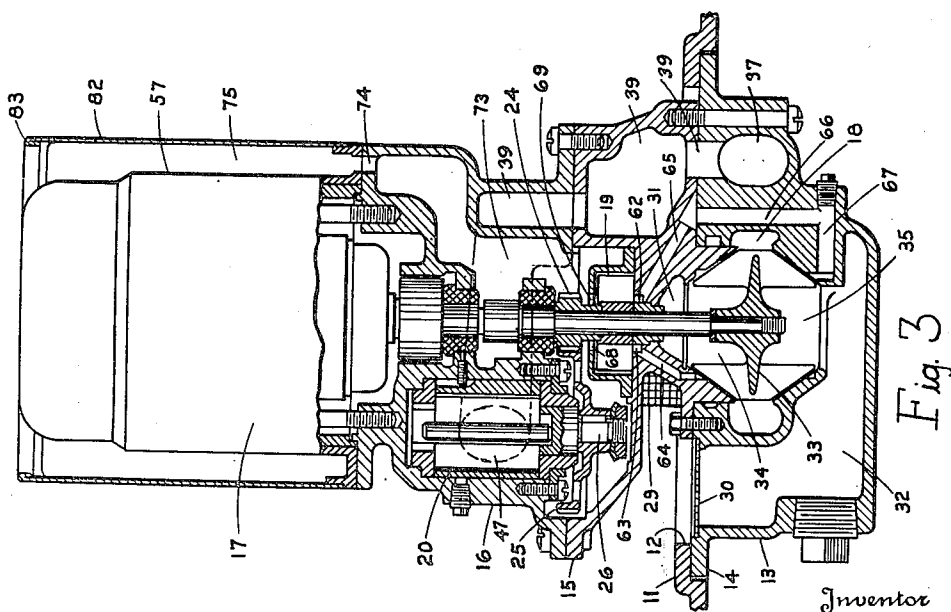
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Inventor

Harold E. Adams

Boys Moses, Walter, Crews + Berry

Attorney S

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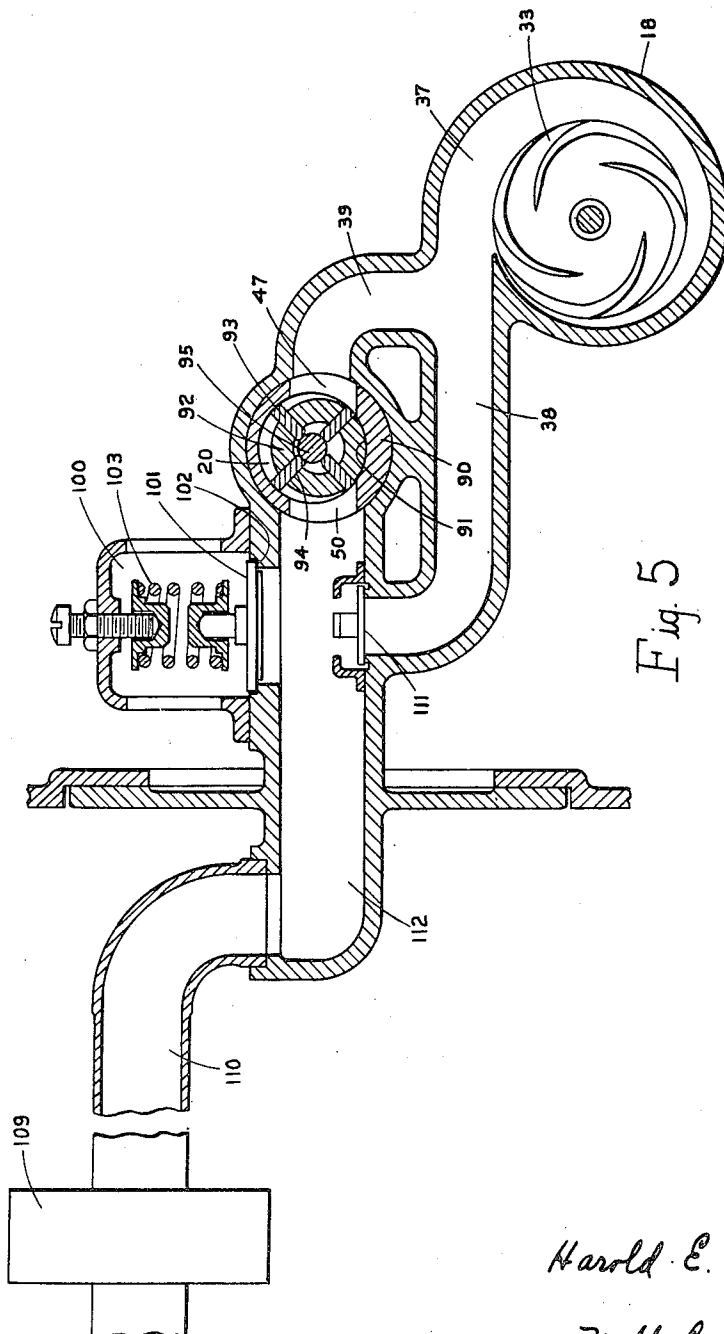
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3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,500,228

PUMP ASSEMBLY

Harold E. Adams, Norwalk, Conn.

Original application September 19, 1945, Serial No. 617,360. Divided and this application March 30, 1946, Serial No. 658,471

22 Claims. (Cl. 103—5)

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The present application is a division of application Serial No. 617,360, filed September 19, 1945, and is concerned with an invention relating to a pumping unit. The broader aspects of the invention are described and claimed in the present application.

Among the objects of the present invention is the provision of a pumping unit combining the characteristics of a self-priming centrifugal pump with a positive type rotary pump to give high capacity, vapor-free delivery of liquid fuel at low pressure and also to give low and intermediate capacity delivery of liquid fuel at high pressure when required. Such a pumping unit is particularly useful in connection with aircraft engines requiring high performance and employing atomizing fuel nozzles for either reciprocating type engines or for revolving gas turbine drive engines and/or jet propulsion. It may, however, be used on other applications requiring similar performance and this invention is not intended to be restricted to this particular field.

A typical application of the pumping unit of the present invention is that of the newly developed art of jet propulsion. Gas turbines employed in this type of propulsion require fuel to be delivered to the atomizing burner nozzles at relatively high pressure such as 300 to 1000 p. s. i. For this purpose, high pressure fuel pumps are normally employed, these pumps being of the gear or piston type or of multistage centrifugal type, as exemplified in my copending application, Serial No. 555,444, now Patent No. 2,438,104 dated March 23, 1948.

Incorporated with the main fuel pump is a system of by-pass or throttle control which automatically varies the amount of fuel required by the engine to maintain its desired speed over varying altitudes. It is a characteristic of this type of propulsion that the fuel requirements decrease with the altitude and unless the fuel is automatically reduced in proportion to the altitude, there is danger of the engine burning up from over-speeding and over-heating. The main engine fuel pump and its control therefore perform a vital function in the successful operation of the airplane and any failure in either the fuel pump or its control would result in possible loss of the airplane.

These jet propelled units are also equipped to burn almost any type of fuel including highly volatile, high octane gasoline fuels principally used on reciprocating type engines. The use of such highly volatile fuel subjects the fuel system to additional difficulty because of the non-lu-

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bricating qualities of the gasoline, which tends to wear out the fuel pump, and also because of the vaporization in the fuel suction lines to these pumps, which causes vapor lock and pump failure.

The use of a fuel booster pump placed in the fuel tank and operating to pressurize the line from the fuel tank to the main engine fuel pump is generally practiced and such pumps as covered in my copending application Serial No. 493,662, now Patent No. 2,461,865, dated February 15, 1949, have been quite successfully used. These centrifugal type fuel booster pumps are only capable of low pressure delivery, which is sufficient to overcome the possible vapor lock formation in the fuel lines. It is highly desirable that such pumps be capable of delivering fuel under high pressure conditions upon emergency, as for example, in case of failure of either the main engine fuel pump or its control.

In accordance with one embodiment of my invention, I include new and improved means for handling the large capacity requirement at low pressure for the purpose of pressurizing the main fuel lines to prevent vapor lock, and also include pumping means which automatically or manually come into action when the requirement arises for starting or for emergency duty at high pressure.

In this structure I use for the high pressure service a vane type rotary pump and make it possible for this pump to deliver fuel against pressures up to 350 p. s. i. and higher. The vane pump also serves as additional scavenging means to aid in priming the centrifugal pump.

In an application of this type, where the motor as well as the pump is immersed in the fuel in the tank and where there is an unusually high horsepower requirement to be met by the motor because of the incorporation within the structure of the high pressure pump, I provide additional means to insure the liquid cooling of the motor by employing a novel arrangement of circulating the liquid discharge from the vapor handling pump into a chamber surrounding the motor. I also depart from normal gear practice by driving the high pressure vane pump thru a train of gears which operate directly in gasoline. Heretofore this was considered impractical because of excessive friction losses due to the operation of gears flooded with liquid, plus the low lubricating qualities of aviation gasoline.

Various other features and advantages of the invention will be apparent from the following particular description and from an inspection of the accompanying drawings, in which:

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Fig. 1 is a side view of one embodiment of this invention in connection with a mounting on the bottom wall of a fuel tank;

Fig. 2 is the bottom plan view of the pump;

Fig. 3 is a cross-sectional view taken along line 3—3 of Fig. 2;

Fig. 4 is a cross-sectional view taken along the lines 4—4 of Fig. 2; and

Fig. 5 is a diagrammatic sectional view showing the arrangement of the passages in connection with a mounting on the side wall of a fuel tank.

Referring to Figs. 1-4 of the drawings, there is shown a fuel tank 10 having a wall 11 such as a bottom wall with an opening 12 through which the pump unit of the present invention passes. This pump unit comprises a body 13 having a flange 14 by which said unit is sealably bolted or otherwise fastened by a leak-proof connection to the bottom tank wall 11, so that the tank opening 12 is sealed. The pump unit is shown including three sections 13, 15 and 16 bolted or otherwise fastened together, and surmounted by an electric motor 17 adapted to drive a centrifugal booster pump 18, a liquid ring type pump 19 for removing the vapor from the fuel in said booster, and a rotary vane type fuel pump 20. For driving these different pumps from the motor 17, the motor shaft 21 is connected to the centrifugal impeller pump shaft 22 by a flexible coupling 23, and a pinion 24 on said impeller pump shaft meshes with a gear 25 on the shaft 26 of the fuel pump 20.

The entire pump unit is of such a height as to be completely submerged in the fuel which is to be pumped from the fuel tank 10. The centrifugal booster pump 18 has a double suction centrifugal impeller 33 with an upper eye 34 and a lower eye 35, the fuel flowing into eye 34 through strainer 29 and inlet chamber 31, and into the lower eye 35 through strainer 30, and inlet chamber 32.

In Fig. 5, the pump unit of Figs. 1-4 is shown diagrammatically, but is shown mounted on the side wall of the fuel tank, instead of on the bottom wall of said tank. However, this showing in connection with a side wall mounting is made to indicate that the pump unit of Figs. 1-4 can be so mounted. In all other respects, the pump unit is similar to that of Figs. 1-4.

As shown diagrammatically in Fig. 5, the booster pump impeller 33 discharges into a volute 37, which in turn discharges into two branch passages 38 and 39. Under normal operating conditions, the main flow of the centrifugal pump is through the connection 38, through a check valve 111 into a chamber 112 and from there through a discharge connection 110, where it goes to the main fuel pump 109 and other controls leading to the burner nozzles.

During the normal operation of the plane and the pump, there is an auxiliary flow created from the centrifugal volute 37 to the conduit 39, where the fuel flows into the vane pump inlet 47, and is discharged from the vane pump outlet 50 into the chamber 112. It is seen, therefore, that flow into the chamber 112 is normally contributed by the vane pump 20 through its discharge 50 and by the centrifugal pump 18 through the check valve 111.

During emergency operation of the unit at high pressure delivery, the vane pump 20 acts as a second stage to the centrifugal pump 18, and discharges into chamber 112 at a higher pressure than capable of by the centrifugal pump, thus

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holding check valve 111 closed and delivering all of the fuel to chamber 112 by the vane pump 20 only.

The motor 17 is completely enclosed by a pressure-tight housing formed by a bell casting 57 and the lower bell casting 16. Liquid-tight gasket joints are formed between these castings in any well-known manner. The bell casting 16 includes a rotating sealing member 59, which is in sealing engagement with a stationary bearing 70. The motor is thus protected from the ingress of liquid fuel from the tank. It is provided with a breather connection 56, and with a seal drain connection 71 to drain off any incipient leakage from the sealing member 59. There are also provided separate conduits (not shown) extending from the inside of the motor 17 to the lower end of the pump casing, which contain the motor electric leads.

The pump 19 serves to remove vapors from the fuel in the pump 18 when handling volatile fuels, such as aviation gasoline. For that purpose, the casing of the pump 18 is provided near the two inlets 34 and 35 thereof with annular gas collecting grooves 60 and 61. The vapors collect in these annular grooves 60 and 61 by centripetal action, and are conducted into the inlet ports 62 and 63 of the liquid ring vapor removal pump 19 by means of the conduits 64, 65, 66 and 67. The general arrangement of the fuel booster pump 18 with the liquid ring vapor removal pump 19 is shown in my copending application, Serial No. 493,662. The pump 19 discharges these vapors after compression through discharge ports 68 and 69 directly below the pinion 24 mounted on the pump shaft 22.

The liquid ring pump 19 discharges air, vapor and liquid upwardly along the pinion 24, and into a discharge chamber 73. This feature of flowing the fuel past the gears 24 and 25 effectively lubricates these gears. Ordinarily, gasoline would be ineffective for that purpose, because of its low lubricating properties. However, these gears 24 and 25 operate right in the gasoline and are lubricated and cooled effectively thereby, because of the high speed at which they operate, and because of the effect of the admixture of air and vapor which is discharged thereagainst by the pump 19 as described. Also, the agitation resulting from the gears 24 and 25 results in their running practically in a pocket of vapor and air bubbles. The breaking up of the fluid around the gears in this manner reduces the friction normally experienced when operating gears in a flooded condition.

The vapor and liquid are then discharged from the chamber 73 upwardly through ports 74 into an annular chamber 75 formed by the outer casing 82 surrounding the motor 17. The air and vapor rise to the surface of the fuel in the tank, and the liquid is discharged into the tank from the top of the chamber 75 or spills over the upper annular edge 83 of the outer motor casing 82, if the fuel level is below this point.

By means of the construction described, advantage is taken of the liquid discharged from the liquid ring vapor removal pump 19 as a means for effectively cooling the motor 17. This liquid is formed around the heated portions of the motor 17 so that by conduction, it removes the heat from said motor thus enabling the motor to operate at high efficiency and with minimum dimensions. Since the motor 17 is liquid-cooled by the expedients described, this cooling is more effective than air cooling. It should be noted that the liquid cooling applied to the motor 17 exists at all times

as long as there is any liquid in the tank 10, even though the liquid level in said tank may be below the level of the motor. In the case of the usual submerged fuel booster pump construction, the motor is not cooled by the liquid in the tank, if the level of the liquid in the tank drops below the level of the motor. Such an arrangement is generally satisfactory for small-powered motors, but where high input is required under emergency conditions, it is highly advantageous to provide a liquid cooling arrangement of the motor such as that of the present invention. This liquid cooling is obtained at no additional cost and power, since the discharge of liquid from the liquid ring vapor removal pump 19 is utilized for this purpose.

The motor 17 is equipped with internal stationary and rotating vanes (not shown) for the internal circulation of air through the field coils and armature to transmit further the heat from these parts to the side walls of the liquid-tight enclosure, which in turn transmits this heat to the circulated liquid by which the heat is carried away.

It should be noted that as a feature of the present invention, protection against vapor binding of the centrifugal pump 18 is additionally afforded by the arrangement of the vane type rotating pump 20. As already indicated, the liquid ring vapor removal pump 19 operates to clear of gas and vapor the suction side of the centrifugal volute in the pump 18. This arrangement is effective in maintaining vapor in bubble-free discharge from the centrifugal pump 18 when handling effervescent liquids, such as volatile aviation gasoline. Under extreme conditions, such as momentary uncovering of the suction, stopping, etc., the centrifugal pump 18 is liable to lose its prime. The liquid ring pump 19 will prime the centrifugal pump upon return of liquid to the centrifugal pump suction. However, in accordance with the present invention, the re-priming is speeded up and aided by the action of the positive displacement rotary vane pump 20, because it exerts a continuous suction on the top of the volute 37 or centrifugal pump discharge 39, and therefore serves to constantly withdraw any gases or vapors collecting at this point. Thus, with the arrangement of the present invention, the centrifugal pump 18 is primed both from its suction side and its discharge side.

The vane pump 20 is in staged relationship with the centrifugal pump 18 for primary use as an emergency high pressure fuel pump. This vane pump 20 comprises a casing 90 having a cylindrical bore 91 in concentric relationship with respect to the pump shaft 26, and a rotor 92 affixed to said shaft. The vane pump 20 is of the sliding vane type having four vanes 93 arranged in quadrant relationship, with each set of two diametrically opposed vanes sliding in slots 94 in the rotor 92. In the central portion of the rotor 92 is located a pin 95, which maintains each opposite pair of blades in close proximity to the wall of the cylindrical bore 91 in the casing 90. This is a general type of vane pump well-known per se. There are many variations of this general type of positive displacement rotary pump, and I do not wish to be limited to this specific rotary pump structure. My invention may equally as well be applied to other positive type piston, gear, lobe and screw pumps.

The vane pump 20 is driven by means of the gear 25 keyed to the motor shaft 26, this gear 25

being in turn driven by the pinion 24 from the main pump shaft 22, as already described.

One characteristic of this type of positive rotary pump 20 is that its operational range is limited by two general factors. When operating at low speed, the maximum pressure obtainable with this pump is low, because of slippage past the blade clearance in the pump. As the pump rotational speed is increased, it is capable of higher pressure, because the increased speed allows less time interval for slippage past each vane or blade 94. The pump 20 by its inherent nature has a fixed displacement per revolution, and as the speed is increased to afford higher differential pressure across the pump, its pumping capacity tries to increase at the same proportionate rate. It soon reaches a point where it is trying to pump liquid faster than the liquid in the suction line can get into the displacement spaces through the suction port of the pump. At this stage in the pump operation, the suction caused by this greater displacement lowers the absolute pressure at the inlet to the pump to a point where it approaches or goes below the vapor pressure of the liquid it is handling. The pump, under these conditions, develops noise and loses liquid capacity and its pressure capability.

Pumps 20 of this nature have been used in the aircraft industry as fuel pumps for a long time, and their pressure when operated alone is limited to around 35 p. s. i. differential and a speed of about 2500 R. P. M. Beyond this speed and pressure, the objectionable noise and rapid disintegration of the pump occurs. Because of this limitation in the operation of the general vane type of rotary pump, in their stead there have been used gear pumps or piston type pumps which can operate at a low speed and at low capacity, and which can deliver the low viscosity liquids against the higher pressures required. Even with pumps of this type, however, they operate at higher pressures to better advantage with high viscosity liquids.

In accordance with my invention, I place the inlet of the conventional vane type rotary pump under pressure so as to enable it to operate at high speeds, and thus obtain high differential pressures, such as 300 p. s. i. and 3500 R. P. M. The pressurizing of the liquid on the inlet side of the rotary pump 20 prevents the cavitation normally experienced at these high speeds, and completely charges the inlet of the vane pump with liquid fuel below the vapor pressure point of the fuel.

The arrangement of the different pumps has already been explained in connection with the diagrammatic construction shown in Fig. 5. It has been shown in connection with this arrangement, that under normal operation, the vane pump 20 is not doing any work, and is merely by-passing a quantity of fuel while the centrifugal pump 18 is pumping through conduits 38 to 112. The centrifugal pump 18, however, is a variable volume pump, varying with pressure when operating at the constant speed, whereas, the vane type rotary pump 20 is essentially a positive fixed volume type when operated at a fixed speed.

In the case of this combination, the centrifugal pump impeller 33 has many times the capacity of the vane type rotary pump 20. Therefore, most of the flow through the connection 110 comes from the centrifugal pump 18 through its discharge check valve 111, when operating under normal pressure conditions, that is, under normal pressure conditions within the normal operating

speed range of the centrifugal pump. Under emergency conditions, such as in the case of the failure of the main engine fuel pump or in starting up the main engine where higher pressures are required than the centrifugal pump is capable of, an automatic action takes place when the discharge line 110 is throttled or requires higher pressure because of such emergencies. When this emergency occurs, resulting in the building up of pressure in the discharge line 110 and the chamber 112, and this pressure continues to build up to points higher than that which the centrifugal pump 18 alone is capable of, the vane pump 20 automatically comes into action.

It is well known that a centrifugal pump such as 18, when operating at a given speed, reaches a maximum pressure when its discharge is throttled, beyond which pressure it ceases to deliver. When this critical pressure is approached (in this case about 30 p. s. i.), the centrifugal pump 18 delivers its maximum pressure to the vane pump inlet 47 at a capacity lower than its normal operating capacity, but equal to the displacement capacity of the rotary pump. The vane type pump 20 then discharges this liquid into the chamber 112 and to the discharge line 110 at the emergency pressure required in this line.

Any back flow of liquid discharged from the vane pump 20 through its discharge port 50 into the chamber 112 is prevented by the automatic closing of the check valve 111, when the pressure in chamber 112 is greater than that in conduit 38. The discharge line beyond the connection 110 may build up to a point where extremely high pressures are obtained to take care of emergency conditions, such as the failure of the main engine fuel pump or its controls, as previously stated. Such data, however, must be within the limits of the motor 17 and the vane type rotary pump 20.

As a protection against the overloading of the motor 17 in cases where higher pressures should be encountered by the pumps than that for which they were primarily designed, a relief valve assembly 100 is provided. This valve assembly comprises a poppet type valve 101 held on its seat 102 by an adjustable spring 103 so arranged that when the desired maximum relief point is reached in the discharge conduit 112, the valve 101 will open and will cause the liquid to discharge back into the tank 10 in which the complete pump unit is located.

As many changes can be made in the above apparatus, any many apparently widely different embodiments of this invention can be made without departing from the scope of the claims, it is intended that all matter contained in the above description, or shown in the accompanying drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. In combination, a fuel feed line for an internal combustion unit having a main fuel pump therein, a fuel booster pump, an emergency fuel pump, means for operating said fuel booster pump and said emergency fuel pump simultaneously, said pumps having respective discharges connecting into said fuel feed line, said fuel booster pump having a branch discharge connecting into the inlet of said emergency pump to operate said fuel booster pump in stage relationship to said emergency pump, and a check valve permitting flow of fuel from the first-mentioned booster pump discharge into said fuel feed line, but blocking flow in opposite direction.

2. The combination as described in claim 1,

in which said emergency fuel pump is of the rotary vane type, and said fuel booster pump is of the centrifugal type.

3. A pump assembly comprising a main fuel pump for delivering fuel to a line adapted to feed an internal combustion unit, an emergency fuel pump of the rotary vane type having a discharge leading to said line, a fuel booster pump of the centrifugal type having two branch discharge connections, one of said branch connections leading to said line and the other to the inlet of said emergency fuel pump, and means for operating said emergency fuel pump and said fuel booster pump simultaneously, said emergency fuel pump being effective as a subsequent pressure stage to said fuel booster pump upon failure of said main fuel pump to supply fuel at the required pressure into said line to make up the deficiency in said required pressure.

4. In combination, a main fuel pump for a feed line leading to an internal combustion unit, a fuel booster pump for said main fuel pump having means for separating the gases from the fuel being pumped and collecting them near the inlet of said booster pump, said booster pump having two branch outlets, one of which is connected to the inlet side of said main fuel pump, a gas removal pump for pumping the collected gases from said fuel pump, and an emergency fuel pump adapted to deliver fuel to said feed line upon failure of said main fuel pump to deliver fuel into said line at the required pressure, said emergency fuel pump having its inlet connected to the other of said branch outlets.

5. The combination as described in claim 4, in which said booster pump is of the centrifugal type with an axial inlet and a peripheral volute discharge, and has an annular gas collecting chamber in its casing surrounding said inlet, and said emergency fuel pump is of the positive type.

6. A pump unit comprising a fuel pump, an electric motor for driving said pump, a gas removal pump for removing the gas from the fuel worked in said fuel pump, and passage means for the discharge from said gas removal pump extending in heat exchange relationship with the heatable parts of said motor.

7. A pump unit comprising a fuel pump, a gas removal pump for removing the gas from the fuel worked in said pump, a pair of intermeshing gears for driving one of the members of said pump unit, and passage means for the fluid discharge from said gas removal pump extending in communication with said intermeshing gears, whereby said gears are lubricated by said fluid discharge.

8. A pump assembly adapted to be immersed in the fuel in a tank, and comprising a fuel pump, a gas removal pump for removing the gas from the fuel worked in said fuel pump disposed above said fuel pump, and a pair of intermeshing gears disposed above said gas removal pump for driving one of the members of said assembly, said gas removal pump having its fluid discharge passage in communication with said gears, whereby said gears are lubricated by said fluid discharge.

9. In a pump assembly, the combination comprising a fuel pump having a drive shaft, a motor for driving said shaft, a gas removal pump for removing the gas from the fuel worked in said pump, a gear transmission for driving one of the members of said assembly from said drive shaft, and passage means for the fluid discharge from said gas removal pump extending in com-

munication with said gear transmission, whereby said transmission is lubricated by said fluid discharge.

10. A pump unit as described in claim 9, in which said passage means also extends into cooling heat exchange relationship with the heatable parts of said motor.

11. A pump unit adapted to be immersed in the fuel in a tank comprising a fuel booster pump of the centrifugal type having a drive shaft, a motor for driving said shaft located above said pump, a gas removal pump disposed above said booster pump and below said motor for removing the gas from the fuel worked in said booster pump, an emergency pump, a gear transmission above said gas removal pump and below said motor for driving said emergency pump from said motor, and passage means for the fluid discharge from said gas removal pump extending upwardly in communication with said intermeshing gears, whereby said gear transmission is lubricated by said fluid discharge, and extending also in cooling heat exchange relationship with the heatable parts of said motor.

12. In a pump assembly, the combination comprising a main fuel line having a main fuel pump therein, a fuel booster pump having an inlet adapted to be connected to a source of fuel supply, and having two branch outlets, one of said outlets being connected to the fuel line on the inlet side of said main fuel pump, a check valve in said last-mentioned outlet to prevent reverse flow in said latter outlet, and an emergency fuel pump having a discharge leading towards said fuel line on the inlet side of said main fuel pump, the other of said outlets leading to the inlet of said emergency fuel pump, whereby said emergency fuel pump is adapted to be effective as a subsequent pressure stage to said fuel booster pump to deliver fuel into said fuel line when required at pressures higher than capable by said fuel booster pump.

13. A pump assembly comprising a main fuel pump, a fuel booster pump for pressurizing the inlet side of said main fuel pump in a fuel feed line, said fuel booster pump having a drive shaft, a motor for driving said shaft, a gas removal pump for removing the gas from the fuel worked in said fuel booster pump, an emergency fuel pump for delivering fuel to said feed line upon failure of the main fuel pump to deliver fuel at the required pressure into said line, a gear transmission for driving said emergency fuel pump from said drive shaft, and passage means for the fluid discharge from said gas removal pump extending in communication with said gear transmission, whereby said transmission is lubricated by said fluid discharge.

14. A liquid pump assembly comprising an inlet connection, a discharge connection having a main pump, a centrifugal pump connected at its inlet to said inlet connection and having two branch discharge conduits, one of said branch conduits connecting into said discharge connection, a check valve in said last-mentioned branch conduit to prevent back flow towards said centrifugal pump, a shaft for driving said centrifugal pump, a frame housing for said centrifugal pump, and a positive type rotary pump in said housing driven from said shaft, and adapted to discharge into said discharge connection, the other branch conduit leading to the inlet of said rotary pump, whereby said centrifugal pump and said positive type rotary pump operate in two stage relationship, and in combination afford

the low head, high capacity of a centrifugal pump and the staged high pressure and low capacity of a positive pump.

15. In combination, a main pump, a high capacity-low head booster centrifugal pump, for said main pump on the inlet side thereof, a low capacity-high head positive rotary pump, means for by-passing at least the main part of the discharge from said centrifugal pump around said positive rotary pump to obtain high capacity low head operation, and means for operating said pumps in pressure stage series and for rendering said by-passing means ineffective to obtain low capacity high head operation.

16. The combination as described in claim 15, comprising a common drive shaft for said pumps, and a common frame housing for said centrifugal pump and said positive pump to join said centrifugal pump and said positive pump in one self-contained unit.

17. A pump assembly comprising a fuel-line, a main fuel pump for delivering fuel to said line, a fuel booster pump for delivering fuel from a fuel source to the inlet of said main fuel pump, an emergency fuel pump in subsequent pressure stage relationship with said fuel booster pump, and power driven means for operating said fuel booster pump and said emergency fuel pump simultaneously and continuously, said emergency fuel pump being responsive to the inlet pressure of said main fuel pump for supplying fuel into said line at a pressure sufficient to make up the deficiency in the required pressure at the outlet of said main fuel pump resulting from the failure of said main fuel pump to maintain said required pressure.

18. A pump assembly comprising a fuel line, a main fuel pump for delivering fuel to said line, a fuel booster pump on the inlet side of said main fuel pump for normally delivering fuel from a fuel tank to the inlet of said main fuel pump, an emergency fuel pump in subsequent pressure stage relationship with said fuel booster pump, and power driven means for operating said fuel booster pump and said emergency fuel pump simultaneously and continuously, said emergency fuel pump having a discharge connection to the inlet side of said main fuel pump and being responsive to the inlet pressure of said main fuel pump for supplying fuel into said line at a pressure sufficient to make up the deficiency in the required pressure at the outlet of said main fuel pump resulting from the failure of said main fuel pump to maintain said required pressure.

19. A pump assembly comprising a fuel line, a main fuel pump for delivering fuel to said line, a fuel booster pump for delivering fuel from a fuel source to the inlet of said main fuel pump, a third fuel pump of the positive displacement type in subsequent pressure stage relationship with said fuel booster pump, and power driven means for operating said fuel booster pump and said third fuel pump simultaneously and continuously, said third fuel pump being responsive to the inlet pressure of said main fuel pump for supplying fuel into said line at a pressure sufficient to make up the deficiency in the required pressure at the outlet of said main fuel pump resulting from the failure of said main fuel pump to maintain said required pressure.

20. A pump assembly comprising a fuel line, a main fuel pump for delivering fuel to said line, a fuel booster pump of the centrifugal type for delivering fuel from a fuel tank to the inlet of

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vane rotary type in subsequent pressure stage relationship with said fuel booster pump, and power driven means for operating said fuel booster pump and said third fuel pump simultaneously and continuously, said third fuel pump being responsive to the inlet pressure of said main fuel pump for supplying fuel in said line at a pressure sufficient to make up the deficiency in the required pressure at the outlet of said main fuel pump resulting from the failure of said main fuel pump to maintain said required pressure.

21. A pump assembly comprising a fuel line, a main fuel pump for delivering fuel to said line, a fuel booster pump for normally delivering fuel from a fuel tank to the inlet of said main fuel pump at the required pressure, an emergency fuel pump normally ineffective to supply fuel at the required pressure into said line, at the inlet of said main fuel pump means for mechanically operating said emergency fuel pump and said fuel booster pump simultaneously and continuously and for delivering substantially all of the discharge from said booster pump to the inlet of said emergency fuel pump, to render said emergency fuel pump effective as a subsequent pressure stage to said fuel booster pump and to supply thereby fuel into said line at the inlet of said main fuel pump at a pressure sufficient to make up any deficiency in the required pressure in said line, and means for rendering the last mentioned means automatically operable upon failure to maintain the required pressure in said line at the inlet of said main fuel pump.

22. In combination, a centrifugal type fuel pump with an axial inlet and peripheral volute

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discharge and with an annular gas collecting chamber in its casing surrounding said inlet, a liquid ring gas removal pump for pumping the collected gases from said chamber, a third positive displacement type pump arranged for two stage operation with said centrifugal pump and for removal of gases collecting in the peripheral volute discharge of said centrifugal pump, and a single power driven means for operating said centrifugal pump, said liquid ring gas removal pump and said third positive type pump simultaneously and continuously, whereby said centrifugal pump is primed both from its suction and its discharge side.

HAROLD E. ADAMS.

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