

Oct. 22, 1946.

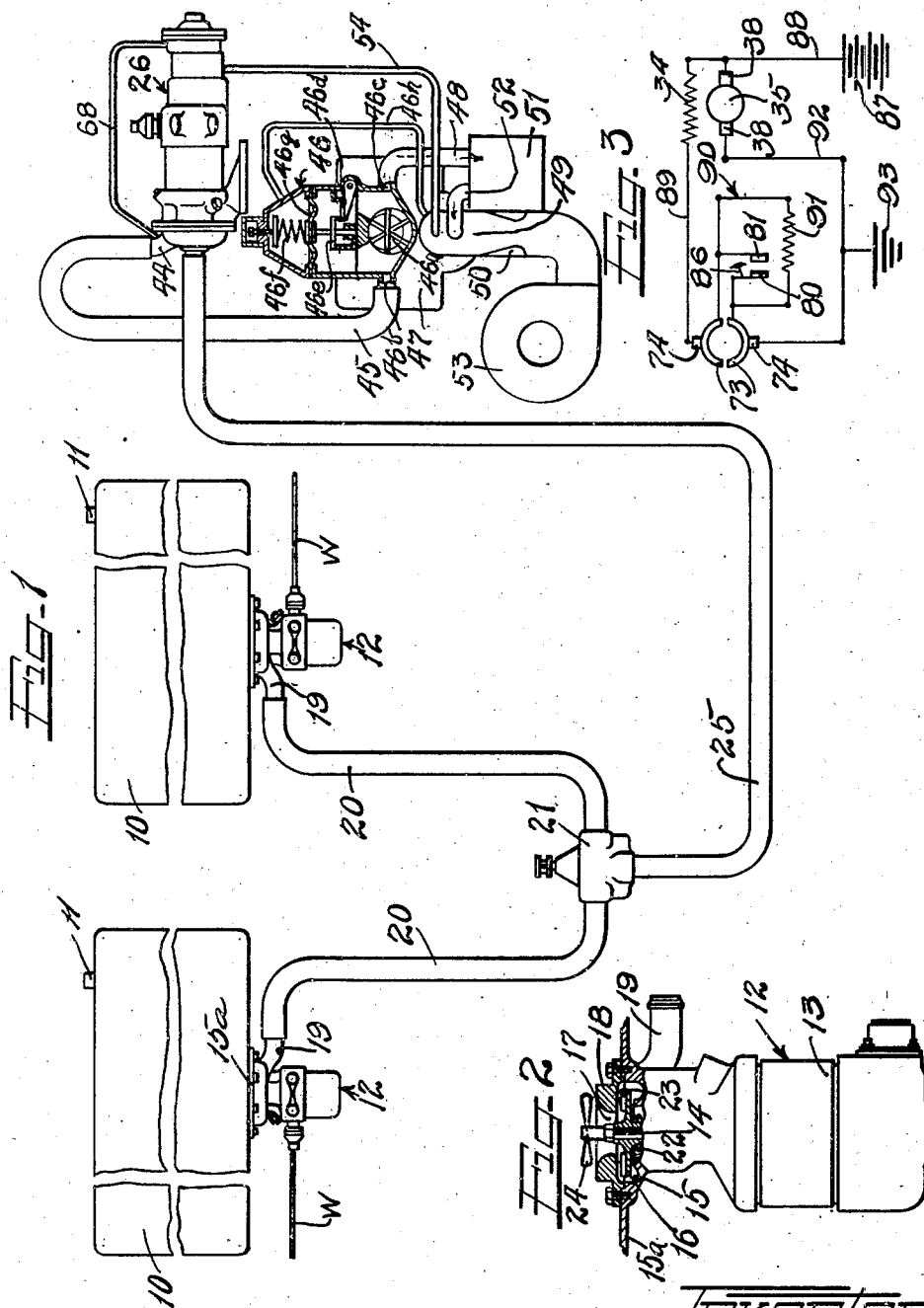
R. R. CURTIS

2,409,931

FUEL SYSTEM

Filed June 4, 1943

2 Sheets-Sheet 1



Inventor
Russell R. Curtis

By Charles W. Hills Att. S.

Oct. 22, 1946.

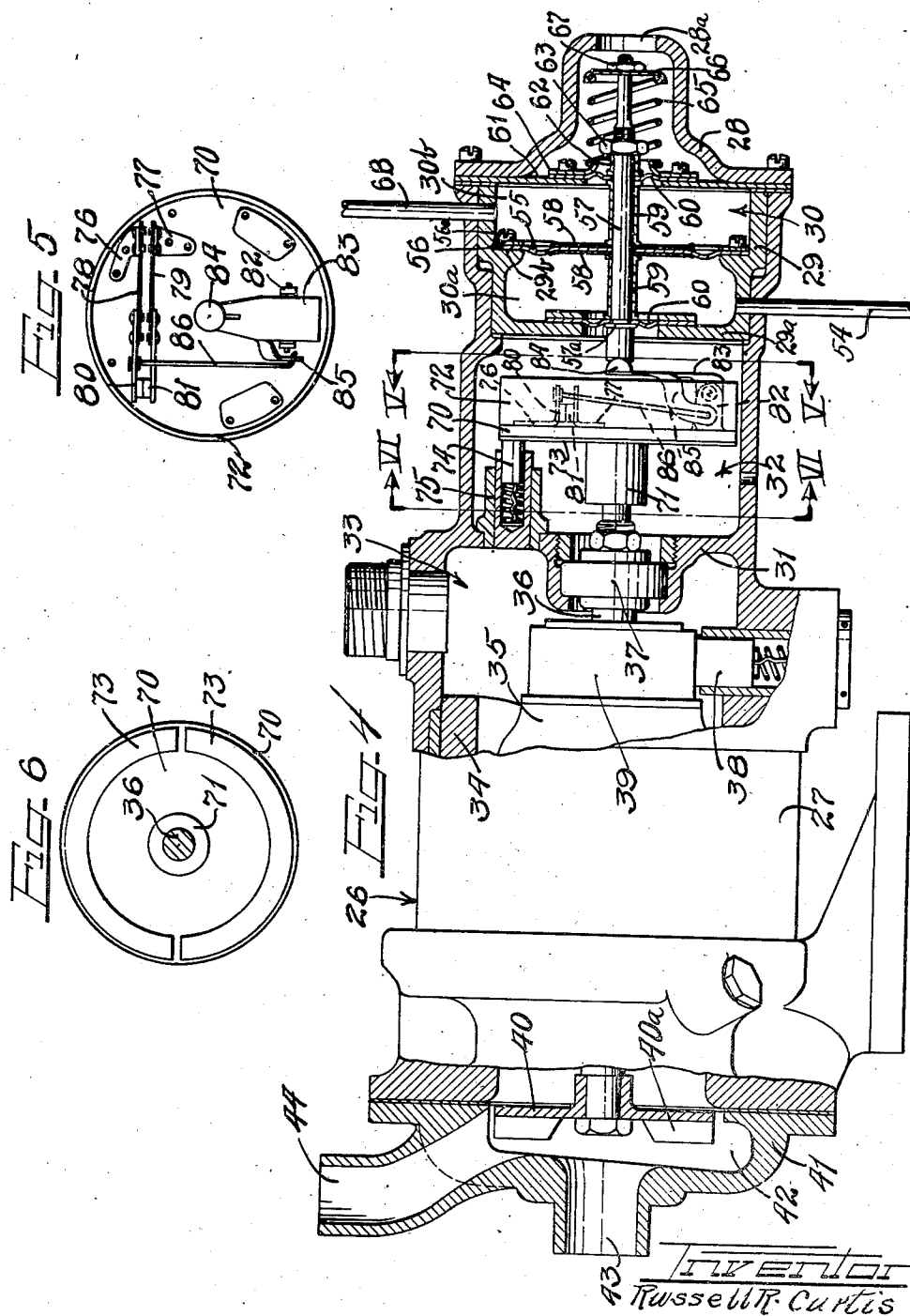
R. R. CURTIS

2,409,931

FUEL SYSTEM

Filed June 4, 1943

2 Sheets-Sheet 2



UNITED STATES PATENT OFFICE

2,409,931

FUEL SYSTEM

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

Application June 4, 1943, Serial No. 489,651

14 Claims. (Cl. 158—36.3)

1

This invention relates to automatically controlled pumps capable of maintaining predetermined pressure differentials.

Specifically the invention relates to a fuel system especially adapted for aircraft usage to maintain proper feed of fuel to an engine irrespective of the altitude in which the engine is operating.

The invention will hereinafter be specifically described as embodied in an aircraft fuel system, but it should be understood that the features of this invention are useful in many other systems.

In accordance with this invention, the fuel tanks of an airplane are vented to the ambient air, and each carries an individual electric motor-centrifugal booster pump unit capable of separating or rejecting gases and vapors from the liquid fuel and pressuring fully liquid fuel into an emergency electric motor-driven booster pump unit. A selector valve is preferably provided between the tank mounted booster pump units and the emergency booster pump unit so that fuel can be selectively fed from one or more tanks into the emergency booster pump unit. The emergency booster pump unit, like the tank pumps, is of the centrifugal type having the inlet and outlet thereof in constant communication even when the unit is idle. Normally this emergency unit is idle and the tank units pressure the fuel through the emergency unit to the inlet of a positive displacement main fuel pump driven by the aircraft engine. The main fuel pump has a by-pass permitting fuel flow therethrough when it is idle and a relief valve mechanism for maintaining a desired pump pressure differential. When the main fuel pump is damaged or insufficient to supply fuel under the desired pressure to the engine, the emergency unit is used to supply fuel to the engine at the proper pressure.

The electric motor driving the emergency booster pump is automatically controlled to operate the pump for maintaining a constant fuel pressure differential based on the pressure existing in the engine intake manifold at the point where fuel and air to the engine are admixed.

The tank-mounted booster pumps are usually sufficient to maintain proper engine performance even at high altitudes and, as explained above, the emergency booster pump need not normally be used. However, for emergency high pressure duty, for example in case of failure of the main engine-driven fuel pump, the emergency booster pump is placed into operation to add to the pressure produced by the tank mounted booster pumps, for supplying fuel to the engine through the by-pass in the main fuel pump. Since the

2

tank pump, emergency pump, and main pump are all arranged in series or tandem, and all have actual or inherent by-passes, any one of the three pumps will supply fuel to the engine in amounts sufficient to maintain flight when, for example, the other two pumps are damaged or otherwise inoperative.

The tank-mounted booster pump will pressure the fuel from the tank sufficiently to prevent liberation of gases and vapors from the fuel and, at the same time, will beat out bubbles of gas and vapor from the fuel about to enter the pump so that no vapor lock can occur in the fuel conduit.

The emergency booster pump preferably has a direct current electric motor with a shunt field. A resistance circuit is automatically placed in series relation with the shunt field to weaken the field and speed up the motor whenever the discharge pressure of the emergency pump falls below a predetermined differential pressure. The automatic control of the motor speed is brought about through the use of a motor-driven governor having a first contact point which is radially movable under the influence of centrifugal force cooperating with a second radially movable contact point controlled by a flexible diaphragm. One side of the diaphragm is exposed to pump discharge pressure while the other side of the diaphragm is exposed to engine intake manifold pressure. When the contact points are open, the resistance circuit is placed in series with the shunt field of the electric motor. When the contact points are closed, the resistance circuit is by-passed, the motor field strength increases, and the motor speed reduced.

It is, then, an object of this invention to provide a fuel system especially useful in aircraft including a tandem arrangement of booster pumps in advance of a main fuel pump for selective operation to insure high altitude performance of the aircraft.

A still further object of the invention is to provide an aircraft fuel system with a tandem arrangement of booster pumps capable of preventing vapor lock in the system while maintaining a constant predetermined fuel pressure differential based on the aircraft engine intake manifold pressure.

A still further object of the invention is to provide an aircraft fuel system with an emergency booster pump capable of maintaining desired fuel pressures even when the main fuel pump of the aircraft engine is inoperative.

Another object of the invention is to provide an electric motor-driven pump wherein the speed

3

of the electric motor is automatically controlled to maintain a desired pump discharge pressure.

A still further object of the invention is to provide a tandem arrangement of electric motor-operated centrifugal type booster pumps with an automatic control for the speed of at least one electric motor.

A still further object of the invention is to provide a booster pump-main fuel pump type of aircraft fuel system with an emergency booster pump which is automatically driven at a speed for maintaining a predetermined fuel pressure differential.

A still further object of the invention is to provide a fuel system for aircraft engines which includes a tandem arrangement of centrifugal type booster pumps wherein at least one of the pumps is driven at a speed determined by the discharge pressure of the pump and the pressure existing in the engine intake manifold at the point where fuel and air are admixed so as to maintain a constant pressure differential between the fuel pressure and the engine intake manifold pressure at this point.

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 example only, illustrate one embodiment of the invention.

On the drawings:

Figure 1 is a fragmentary and broken somewhat diagrammatic elevational view of an aircraft fuel system according to this invention.

Figure 2 is a side elevational view, with parts broken away and shown in vertical cross section, of one of the tank-mounted booster pumps in the system of Figure 1.

Figure 3 is a wiring diagram for the emergency booster pump unit shown in Figure 1.

Figure 4 is an enlarged side elevational view, with parts in vertical cross section, of the emergency booster pump unit.

Figure 5 is a view taken along the line V—V of Figure 4.

Figure 6 is a view taken along the line VI—VI of Figure 4, the brush elements being omitted.

As shown on the drawings:

In Figure 1 the reference numerals 10, 10 designate fuel tanks of an airplane (not shown). These tanks 10, 10 are vented to the ambient air through vent openings 11, 11 in the top walls thereof. Each tank 10 has an electric motor-driven centrifugal booster pump unit 12 mounted on the bottom wall thereof.

As best shown in Figure 2, each booster pump unit 12 includes a casing 13 housing an electric motor (not shown) which is energized through electric wires such as W (Figure 1). The electric motor has a drive shaft 14 projecting through a pump casing 15 from the motor casing 13. The pump casing 15 has an outturned flange 15a which is directly bolted on the bottom wall of a tank 10 as shown in Figure 1.

The pump casing 15 defines a pump volute chamber 16 with a central inlet 17 defined by a throat ring 18 projecting into the tank to freely communicate with the lower portion of the tank.

Fuel can flow by gravity through the inlet 17 into the volute chamber 16 and thence through an outlet 19 communicating with the periphery of the volute chamber into a pipe line 20 connected to an inlet of a selector valve 21. The arrangement is such that fuel can flow from the

4

tank 10 into the selector valve 21 even though the pump unit 12 is not being operated.

An impeller 22 (Figure 2) is mounted on the drive shaft 14 and has upstanding pumping vanes 23 thereon underlying the throat ring 18 to centrifugally propel fuel from the inlet 17 through the volute chamber 16 and into the pipe line 20. In addition, a propeller 24 is mounted on the drive shaft 14 in advance of the pumping vanes 23. This propeller is disposed in the tank and acts on fuel about to enter the pump unit 12 before the fuel reaches the pumping vanes 23 and is trapped in the pump. The propeller 24 serves to beat out bubbles of gas and vapor from the fuel and laterally ejects these bubbles away from the pumping vanes 23 so that, when the pump is operating, only fully liquid fuel is pressured into the fuel line 20. The rejected bubbles of gas and vapor will rise to the surface of the fuel in the tank 10 where they will burst to discharge the gases and vapors out of the tank through the vent 11.

The selector valve 21 has an outlet communicating with a fuel pipe 25. This fuel pipe 25 conducts fuel from the selector valve 21 to an emergency duty electric motor-centrifugal booster pump unit 26.

As shown in Figure 4, the unit 26 includes a generally cylindrical open-ended casing 27 with a cap 28 closing one open end thereof, a cup member 29 seated in the open end closed by the cap 28 and having a partition wall 29a providing a diaphragm chamber 30 in this end of the casing. A second partition wall 31 is provided intermediate the ends of the casing 27 in spaced relation from the partition wall 29a to provide a governor chamber 32 in the casing. A motor compartment 33 is provided by the casing 27 and houses an electric motor field or stator 34 and an electric motor armature or rotor 35. The armature or rotor 35 is rotatably mounted on a shaft 36 carried by casing-supported bearings such as 37. The casing 27 also carries brushes such as 38 for engaging the commutator 39 of the rotor or armature 35. An impeller 40 is mounted on the shaft 36 and projects beyond the other open end of the casing 27. This open end of the casing 27 is covered by means of a cap 41 defining a pump volute chamber 42 and having a central inlet 43 receiving the pipe 25 together with a peripheral outlet 44 receiving a discharge pipe 45 as shown in Figure 1.

The inlet 43 and outlet 44 are always in communication irrespective of whether or not the impeller 40 is being driven. When the impeller 40 is being driven, the pumping vanes 40a thereon will centrifugally pressure fuel from the inlet 43 through the volute 42 into the outlet 44.

As shown in Figure 1, the pipe 45 from the outlet 44 of the unit 26 communicates with the inlet of a main fuel pump 46 mounted on and driven by the aircraft engine 47. The fuel pump 46 which is diagrammatically shown is of the positive displacement type including a vaned rotor 46a between the inlet 46b and outlet 46c thereof for pressuring fuel from the pipe 45 to a pipe 48. A by-pass valve 46d is adapted to connect the inlet and outlet around the rotor 46a whenever inlet pressure is greater than outlet pressure. A relief valve 46e is adapted to relieve fuel from the outlet back to the inlet to maintain outlet pressure at a constant pressure differential based on either ambient air pressure or engine intake manifold pressure and selectively determined by an adjustable spring 46f urging the relief valve toward closed position. A diaphragm 46g is ar-

5

ranged for co-movement with the valve 46e. In order that the spring 46f can be the determining factor for maintaining the selective pressure differential, it is preferred that one side of this diaphragm have an effective area exposed to the engine manifold pressure through a tube 46h connected to the manifold 49 of the engine 47 that is balanced by an equal area on the valve 46e exposed to the pump outlet pressure.

The intake manifold 49 of the engine 47 has an air pressure-controlled variable Venturi throat 50 controlling flow of fuel through a carburetor 51 receiving the pipe line 48 and having a discharge line 52 connected to the engine intake manifold at a point closer to the engine than the throat 50. An air supercharger or air pump 53 is provided to force air through the Venturi throat 50. Air from the supercharger 53 admixes with fuel from the fuel line 52 in the manifold 49.

The engine intake manifold 49 has a tube 54 leading therefrom at the point therein adjacent the point where fuel from the carburetor and air from the supercharger are admixed. This tube 54, as shown in Figure 4, communicates with the interior of the cup member 29 in the casing 27 between the wall 29a of the cup and a shoulder 29b on the cup. This shoulder has a diaphragm disk 55 held thereon in sealing relation by means of a washer 56 and cap screws 56a extending through the washer and threaded into the shoulder 29b. The diaphragm 55 snugly embraces a shaft 57 extending through the cup member and projecting into the cap 28 and also into the chamber 32. Metal disks 58 overlie the central portion of the diaphragm 55 on both faces thereof and are abutted by tubes 59 seated on the shaft 57. Each of these tubes has outturned flanges at the ends thereof, one set of which engage the washers or disks 58 and the other set of which engage small diaphragms 60 respectively carried around their peripheries by the partition wall 29a of the cup 29 and by an apertured metal disk 61 between the end cap 28 and the open end of the cup 29. The shaft 57 has an integral collar portion or head 57a spaced from the end thereof which projects into the chamber 32 effective to clamp the adjacent diaphragm 60 between the end of a tube 59 and the collar 57a thereby providing a sealed compartment 30a in the chamber 30 on one side of the diaphragm 55. The other small diaphragm 60 is sealingly clamped by the other tube member 59 and by a ferrule or tube 62. The ferrule or tube 62 is acted on by a nut 63 threaded on the shaft 57. The diaphragm seal 60 thus provides a second compartment 30b in the chamber 30 on the other side of the diaphragm 55.

A spring retainer 64 overlies the seal 60 on the plate 61 and receives a coiled spring 65 therearound. A second spring retainer 66 receives the other end of the coiled spring 65 and a nut 67 on the end of the shaft 57 adjustably positions the retainer 66 to control compression of the spring 65. The spring 65 tends to urge the shaft 57 away from the chamber 32 into which said shaft projects. The end cap 28 defines a recess receiving the spring retainers and spring and the end of the end cap 28 is preferably apertured as at 28a so that the nut 67 is accessible from the outside to control the compression of the spring 65.

A tube 68 joins the compartment 30b with the discharge side or outlet 44 of the pump.

Thus one side of the diaphragm 55 is exposed

6

to engine intake manifold pressure through the tube 54 tending to shift the shaft 57 out of the chamber 32. The other side of the diaphragm 55 is exposed to pump discharge pressure through the tube 68 tending to shift the shaft 57 further into the chamber 32. The diaphragm seals 60 permit shifting of the shaft while sealing the compartments 30a and 30b on opposite sides of the diaphragm 55.

The compression of the spring 65 can be set by the position of the nut 67 to oppose, with any desired force, shifting of the shaft 57 further into the chamber 32 and thereby opposing the pump discharge pressure acting through the tube 68 on the diaphragm 65 from shifting the shaft. As a result of this adjustment, once the spring is set to maintain a desired pressure differential between pump discharge pressure and engine intake manifold pressure, the shaft will only be shifted upon variation of the pressure differential between the compartments 30a and 30b which compartments are respectively under manifold pressure and pump pressure.

A disk 70 has a hub portion 71 keyed or otherwise secured to the motor shaft 36 in the chamber 32 of the casing 27. This disk has an upstanding circular flange 72 surrounding the same and providing an open cup facing the partition wall 29a of the cup 29. The other face of the disk carries a pair of segmental circular contact rings 73 as best shown in Figure 6. Two brushes such as 74 carried in ferrules such as 75 by the partition wall 31 are spring-urged against the contact rings 73.

As shown in Figures 4 and 5, the face of the disk 70 opposite the face carrying the contact rings 73 carries a pair of opposed brackets 76 and 77. The bracket 76 carries a leaf spring 78 while the bracket 77 carries a leaf spring 79. The leaf springs 78 and 79 project across the face of the disk in spaced opposed parallel relation with the spring 78 being radially outward of the spring 79. The spring 78 carries a contact point 80 and the spring 79 carries a contact point 81 cooperating with the point 80.

A bracket 82 is secured on the disk 70 and tiltably carries a lever 83 with a button end 84 acted on by the end of the shaft 57. An arm 85 is provided on the lever 83 to actuate a rod or link 86 secured at its end to the outer contact point 80. When the shaft 57 is moved further into the chamber 32, it will tilt the lever 83 and arm 85 to actuate the rod 86 for drawing the contact point 80 radially inward.

The position of the contact point 81 is influenced by centrifugal force and depends upon the speed at which the disk 70 is being rotated.

As shown in the wiring diagram of Figure 3, current from a battery or other source 87 is fed through a wire 88 through both the stator 34 and rotor 35 of the electric motor for the emergency booster pump 26. A wire 89 connects the stator or field 34 with the contact rings 73 through one brush 74. The contact rings 73 are joined through a circuit 90 including additional field windings or resistance 91 in series with the field 34 whenever the contact points 80 and 81 are separated. A wire 92 connects the armature 35 and contact rings 73 through the other brush 74 with the ground 93.

When the contact points 80 and 81 are together, the resistance 91 is removed from the circuit 90.

Since a motor with a shunt field is used, addi-

tion of resistance 91 to the field will weaken the field and cause the motor to operate at increased speed. Therefore, whenever the points 80 and 81 are separated, the motor will be operating at high speed. Whenever the points 80 and 81 are together, resistance is taken out of the field circuit, the field is strengthened, and the motor will operate at reduced speed.

As explained in connection with Figures 4 and 5, the radial position of the contact point 81 is controlled by the speed of the disk 70 under the influence of centrifugal force since the contact point 81 will tend to fly outwardly. However, the radial position of the contact point 80 is controlled through the link rod 86 and lever 83 by the position of the shaft 57. Therefore the speed at which the contact point 81 will reach the contact point 80 depends upon the position of the shaft 57.

As explained hereinabove, the position of the shaft 57 is controlled by the spring 65 and by the difference in pressure or pressure differential between the compartments 30a and 30b. The compartment 30a is under engine intake manifold pressure while the compartment 30b is under pump discharge pressure. Therefore adjustment of the spring 65 will predetermine the speed at which the contact points will close and will serve to maintain a predetermined pressure differential between pump discharge pressure and engine intake manifold pressure. If the pump discharge pressure increases above the desired differential, the diaphragm 55 will shift the shaft 57 further into the chamber 32 thereby drawing the contact point 80 radially inward and maintaining closed position of the points at lower speeds. The motor will thereby slow down and the pump pressure will be decreased. On the other hand, if the intake engine manifold pressure should increase relative to the pump discharge pressure, the action of the spring 65 to retract the shaft from the chamber 32 will be assisted by pressure in the compartment 30a. This will permit the contact point 80 to assume a more outward position under the influence of centrifugal force and the contact points will not be closed until a higher speed is reached thereby speeding up the motor and increasing the pump pressure to bring it up to a predetermined differential above the increased engine intake manifold pressure.

Thus, the diaphragm and centrifugal governor control for the emergency pump unit 25 make possible the use of this unit in place of the engine driven main pump 46 in the event that the pump 46 becomes inoperative and in such event the engine will continue to receive sufficient fuel under the desired pressure to maintain high altitude flight the same as when the main pump is operating. The emergency pump can maintain the same fuel pressure differential as the main pump based either on ambient air pressure or engine manifold pressure.

From the above descriptions it should be understood that the invention provides a tandem or series arrangement of pumps including an emergency pump between other pumps in the system which emergency pump can be operated to maintain a predetermined pressure differential of the material being pumped. This pressure differential is preferably based on engine intake manifold pressure of an aircraft engine but without departing from the principles of the invention it can be based on ambient air pressure by merely

exposing the compartment 30a to the ambient air instead of to the engine intake manifold.

At least two of the pumps in tandem are centrifugal type pumps having inlets and outlets in constant communication so that fluid can flow therethrough even when the pumps are inoperative. One of the pumps may be a positive displacement pump with a by-pass therearound.

When the invention is embodied in an aircraft fuel system, a centrifugal type pump is mounted on each fuel tank of the aircraft and is driven by an individual electric motor. These pumps have agitators associated therewith disposed in the tanks to eliminate gases and vapors from the liquid about to enter the pumps so that vapor lock will not occur. The tank mounted pumps discharge through a selector valve having a plurality of inlets which can be placed in communication with each other together with an outlet communicating with the emergency pump. The tank-mounted pumps can thus be used to transfer fuel from one tank to another by positioning the selector valve 21 so that two of its inlets are in communication.

It will, of course, be understood that various details of construction may be varied through a wide range without departing from the principles of this invention and it is, therefore, not the purpose to limit the patent granted hereon otherwise than necessitated by the scope of the appended claims.

I claim as my invention:

1. In a fuel system adapted for high altitude aircraft performance, an emergency electric motor-booster pump unit having a pump inlet and an outlet in constant communication with the inlet, a main fuel pump having an inlet communicating with the outlet of the emergency booster pump and having a by-pass therearound, an air supercharger, a carburetor receiving fuel from the main pump, an engine intake manifold receiving air and fuel from the supercharger and carburetor, said electric motor of the emergency booster pump unit having a shunt field, a centrifugal governor driven by said shunt field motor having contact points in the emergency electric motor circuit that are mounted for swinging radially outward under the influence of centrifugal force, a diaphragm exposed on one side to discharge pressure of said emergency booster pump and exposed on the other side to pressure in the intake engine manifold at the point where the fuel and air are mixed, means controlled by said diaphragm for regulating the radial position of one of said contact points, and a resistance circuit adapted to be placed in series with the shunt field of the electric motor driving the emergency booster pump whenever said contact points are separated whereby the field is weakened and the motor speed is increased.

2. In a fuel system including a positive displacement fuel pump, a carburetor receiving fuel from said pump, a by-pass associated with said pump, and a device operated in one direction by air pressure and in the reverse direction by fuel pressure associated with said pump to maintain a constant pressure differential between the fuel pressure at the carburetor inlet and the air pressure existing at the point where the fuel is introduced into the air for forming a combustible mixture; the improvement of a centrifugal pump having an outlet communicating with the inlet of the fuel pump, a driver for said centrifugal pump, and automatic means for controlling the speed of

said driver exposed on one side to centrifugal pump pressure and on the other side to pressure existing at the point where fuel is introduced into the air for forming a combustible mixture whereby said centrifugal pump can take the place of said fuel pump and device to maintain the constant fuel pressure differential.

3. A pump and motor unit comprising an electric motor, a pump impeller driven by said electric motor, means defining a pumping chamber surrounding said impeller and having a central inlet and a peripheral outlet, a centrifugal governor driven by said electric motor including swingable contacts adapted to yield under centrifugal influence to control the speed of the motor, and means for automatically adjusting the contacts of said governor in accordance with the pump discharge pressure to control the speed of the motor for maintaining a constant pump discharge pressure.

4. A pump and electric motor unit comprising an electric motor, a pump impeller driven by said motor, means providing a pumping chamber surrounding said impeller, a resistance circuit, a centrifugal governor including swingable contacts in said circuit adapted to yield under centrifugal influence for placing said resistance circuit in and out of series with said electric motor to control the speed of the motor, and means automatically adjusting the contacts of said governor in accordance with the pressure differential between the pump discharge pressure and a base pressure for regulating the speed of the motor to maintain a constant pump pressure differential.

5. A unit comprising an electric motor having an armature and a shunt field, a pump driven by the armature of said motor, a centrifugal governor driven by the armature of said motor, a contact point swingably mounted on said governor and adapted to swing outwardly under the influence of centrifugal force, a cooperating contact point swingably mounted on said governor, contact rings on said governor, brushes cooperating with said contact rings connecting the same with the field and armature of said motor, a resistance circuit interposed between said contact rings to add resistance to the field of said motor, said contact points arranged to open and close said resistance circuit, and diaphragm means exposed to pump discharge pressure on one side and a base pressure on the other side controlling the radial position of one of said contact points.

6. A pump and motor unit comprising a casing defining a diaphragm chamber, a governor chamber, a motor chamber, and a pumping chamber having an inlet and an outlet, a pump impeller in said pumping chamber between said inlet and outlet, an electric motor in said motor chamber driving said pump impeller, a centrifugal governor in said governor chamber driven by said electric motor, a diaphragm in said diaphragm chamber dividing the chamber into opposed compartments, means controlled by said diaphragm acting on said governor to control the governor in accordance with the pressure differential between the two compartments, and means connecting one of said compartments with the pump outlet.

7. A pump and motor unit comprising an electric motor, a drive shaft driven by said motor, a pump impeller driven by said drive shaft, a disk driven by said drive shaft, a leaf spring carried by said disk, a contact point on said leaf spring adapted to swing outwardly under the influence of centrifugal force, a second contact

point on said disk, a lever controlling the radial position of said second contact point, a diaphragm actuating said lever exposed on one side to pump discharge pressure, and means controlled by said contact points to regulate the speed of said motor.

8. In a pump and electric motor unit a pump casing defining a volute chamber with a central inlet and a peripheral outlet, an impeller in said volute chamber for pressuring fluids from the inlet to the outlet, an electric motor having an armature driving said impeller, and a shunt field cooperating with said armature, a resistance circuit for strengthening and weakening said field, swingable contact devices that are centrifugally influenced for controlling said circuit, and a device exposed to pump discharge pressure on one side and air pressure on the other side for controlling said contact points.

9. In a pump unit an electric motor having a field, a resistance circuit in said field, a pump driven by said motor, a governor driven by said motor including a swingably mounted contact point adapted to move outwardly under the influence of centrifugal force and a cooperating swingably mounted contact point, a spring controlling the position of said cooperating contact point, and a diaphragm coacting with said spring exposed to pump discharge pressure on one side and base pressure on the other side, said contact points when opened adding said resistance circuit to the field of the electric motor causing the motor speed to increase and said contact points when together removing said resistance circuit from the field of the electric motor to slow down the speed of the motor whereby the pump is driven at speeds to maintain a pressure differential above base pressure predetermined by said spring.

10. In a pump system, a centrifugal pump and a main pump in tandem, a device associated with said main pump for maintaining a selected pressure differential above base pressure at the outlet of the main pump, a driver for said centrifugal pump, and an automatic speed control for said driver causing the driver to operate the centrifugal pump at speeds producing the same pressure differential as the main pump.

11. In a pump system, a plurality of pumps in tandem, a device associated with one of said pumps for maintaining a selected pressure differential above base pressure at the outlet thereof, a driver for another of said pumps, and an automatic speed control for said driver for causing the driver to operate said another pump at speeds producing the same pressure differential as said one pump.

12. In a fuel system, an engine driven fuel pump having a device associated therewith for maintaining a desired differential above a selected base pressure at the outlet thereof and a by-pass therearound, a booster pump, conduit means connecting the outlet of the booster pump with the inlet of the fuel pump, a driver for said booster pump, and means actuated by variations in said pressure differential to control the speed of said driver for maintaining the desired pressure differential at the outlet of the fuel pump.

13. In a fuel system adapted for an aircraft engine including an engine-driven positive displacement main pump having a by-pass means therearound, a relief valve associated with said pump, a diaphragm movable with said relief valve having one face exposed to pump inlet

11

pressure and the other face exposed to a selected base pressure, a spring urging said valve toward closed position to maintain a selected pressure differential above the selected base pressure at the outlet of the pump, a fuel tank, and a booster pump receiving fuel from said tank for pressurizing the fuel to the intake of the main fuel pump; the improvement of an emergency centrifugal type pump having an inlet receiving fuel from the booster pump and an outlet for supplying fuel to the intake of the main fuel pump, an electric motor driving said centrifugal pump, and automatic means including a diaphragm having one face exposed to the selected base pressure and the other face exposed to the pressure at the outlet of the centrifugal pump for controlling the speed of the electric motor to cause the centrifugal pump to pressure fuel at the same pressure differential produced by the main pump.

14. In a fuel system for an aircraft engine including a fuel tank, a booster pump having an inlet receiving fuel from said tank and an outlet in constant communication with said inlet, a main fuel pump having an inlet receiving fuel from the outlet of said booster pump and an

12

outlet communicating with the aircraft engine, a by-pass around said main fuel pump connecting said inlet and said outlet thereof, a relief valve in said main fuel pump, a diaphragm movable with said valve having one face exposed to inlet pressure and the other face exposed to a selected base pressure, a spring urging said relief valve to closed position for maintaining a selected pressure differential at the outlet of said pump above the selected base pressure, an electric motor driven centrifugal booster pump having an inlet communicating with the outlet of the first mentioned booster pump and an outlet communicating with the inlet of the main fuel pump, and a centrifugally actuated electric means associated with said electric motor for controlling the speed of said motor, said means including a diaphragm having one face vented to the same selected base pressure as the diaphragm of the main fuel pump and the other face vented to outlet pressure of the centrifugal booster pump whereby said electric motor will be driven at a speed for maintaining a constant pressure differential at the outlet of the main fuel pump.

RUSSELL R. CURTIS.