July 25, 1950 D. SAMIRAN 2,516,149

AIRCRAFT FUEL SYSTEM

Filed May 15, 1945 2 Sheets-Sheet 1

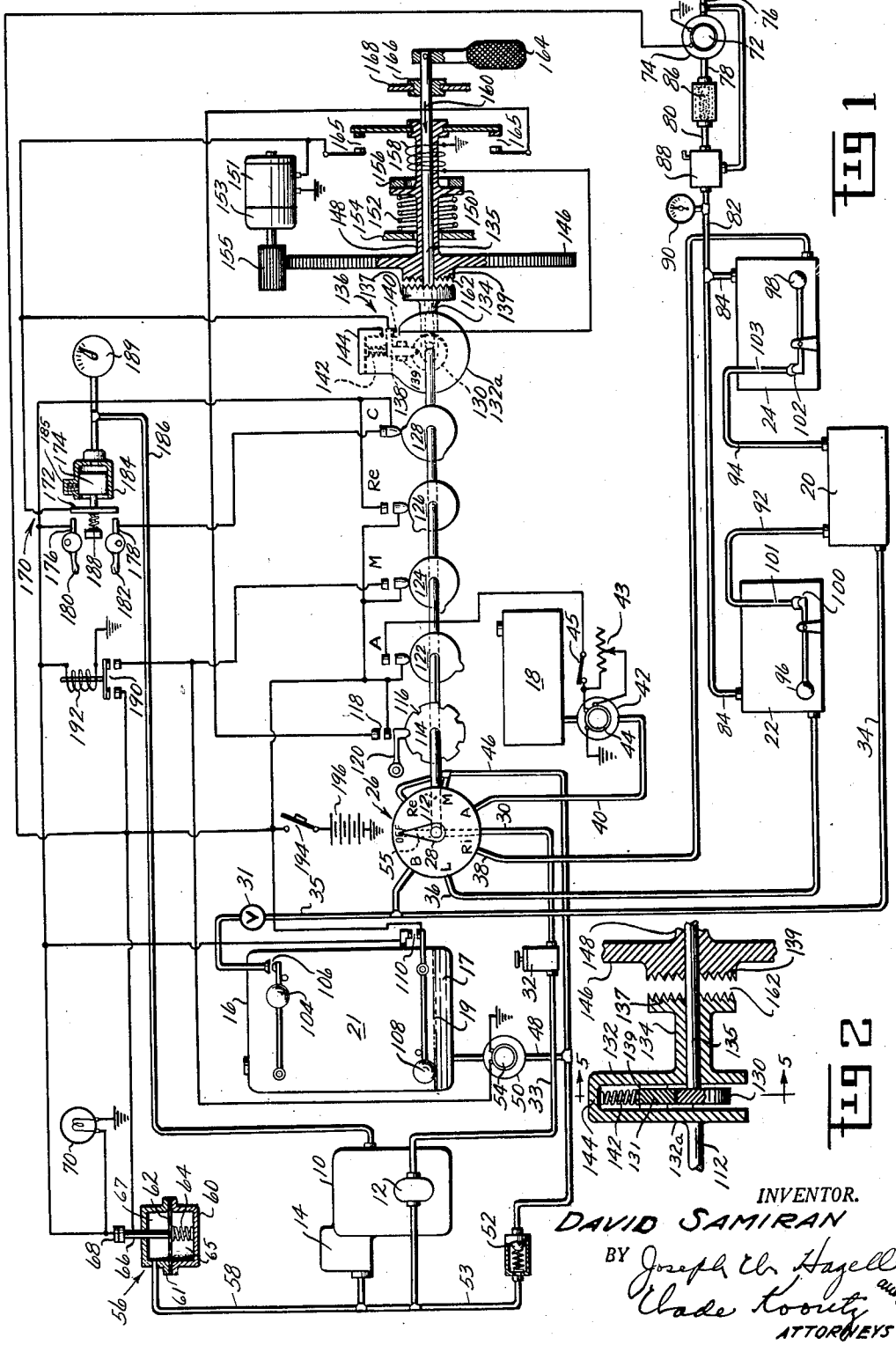

Fig 1

Fig 2

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FIG. 3

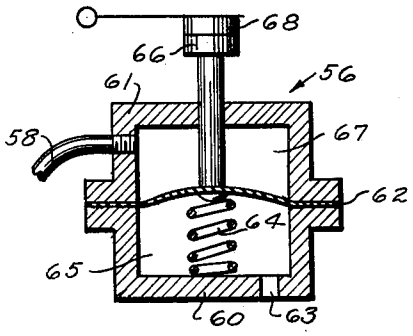


FIG. 4

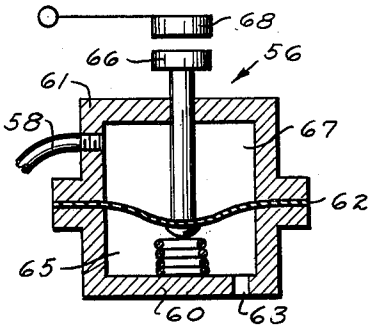


FIG. 5

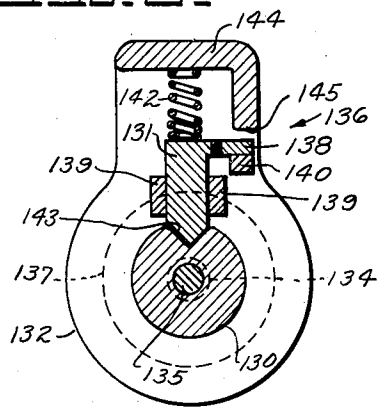


FIG. 6

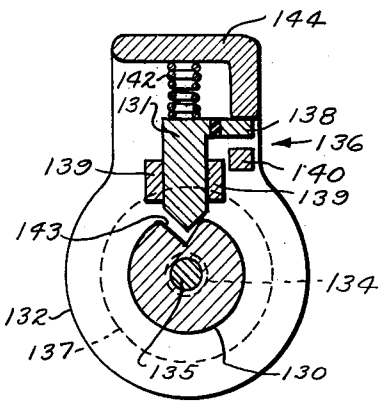


FIG. 7

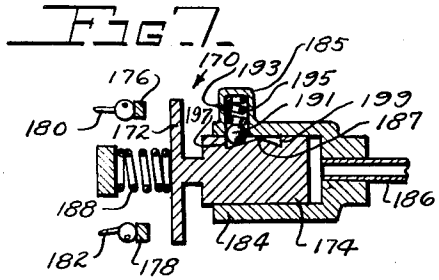
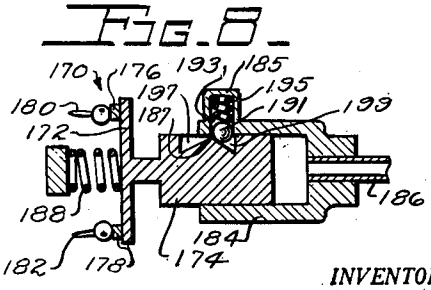


FIG. 8



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UNITED STATES PATENT OFFICE

2,516,149

AIRCRAFT FUEL SYSTEM

David Samiran, Osborn, Ohio

Application May 15, 1945, Serial No. 593,917

8 Claims. (Cl. 158—36)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

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The invention described herein may be manufactured and used by or for the Government for governmental purposes, without the payment to me of any royalty thereon.

This invention relates to fuel systems for aircraft, having particular reference to aircraft for long range missions.

In modern aircraft, particularly in warcraft, it has usually been the practice to carry the fuel supply in a series of separate tanks distributed as uniformly as practicable throughout the craft, this practice having the advantage of better weight distribution and the further advantage that if one tank becomes so punctured as to lose its fuel, the loss will be proportionately less as the number of tanks is greater.

In the more recently proposed fuel systems of this kind, automatic means are usually provided which includes means sensitive to a pressure drop at the carburetor due to an empty tank condition for disconnecting the empty tank from the suction side of the main fuel pump, searching out a full tank, and connecting the pump suction side thereto. Since, with this arrangement, there is an elapse period between the time at which a tank becomes empty and the time at which this fact registers on the pressure sensitive device at the carburetor intake, it is required, in order to insure against engine failure, to provide an emergency pump to pump fuel directly to the carburetor, such emergency pump being operative automatically the instant the device at the carburetor senses the drop in pressure at that point. The emergency pump then continues to operate until the engine pump has built up the pressure at the carburetor by virtue of its reconnection to a full tank.

The practice of employing an emergency pump and connecting it to the discharge side of the engine pump to maintain the fuel pressure at the carburetor between the time that a tank becomes empty and the time that a full tank has been selected and connection made thereto, is not broadly new in this application, since such a system is shown, described and claimed in my copending application Serial No. 475,683, filed February 12, 1943, now Patent No. 2,406,854, issued Sept. 3, 1946. Moreover, fuel systems employing, in addition to the engine pump, an electric booster pump to discharge into the suction side of the engine pump when the fuel cavitates at this point, due to reduced atmospheric pressure at high altitude or to other causes, are also well known in the art.

In the copending application of Samiran and

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Mills, Serial No. 494,128, filed July 9, 1943, now Patent No. 2,435,982, issued Feb. 17, 1948, we disclose a fuel system in which the engine pump is supplemented both by an electrically driven emergency pump and an electrically driven booster pump of the character above described. Insofar as known to applicant, however, a single electrically driven pump has not heretofore been made to perform both functions.

It is therefore another object of this invention to so construct and arrange a fuel system that one and the same electrically driven pump will serve both as an emergency pump to supplement the engine pump upon changing from an empty to a full tank, and as a booster pump for increasing the pressure at the suction side of the engine pump when that becomes desirable.

Inasmuch as it is necessary that a reserve supply of fuel be maintained in some tank so as to always have fuel upon which the emergency pump may draw, it is a further object of this invention to provide means, applicable to one of the tanks which will prevent a reserve volume of fuel in the bottom of said tank from being used until after the last possible other source of supply has been investigated and found to be exhausted.

While in a fuel system of this kind there is usually an automatically operative selector cock for changing from one tank to the next, there are situations when it becomes desirable to turn the selector cock manually at a faster or a slower rate or in the other direction from that in which it is being rotated automatically. It is therefore another object of this invention to provide means associated with an automatic power operated selector cock whereby the simple act of attempting manual operating of the selector cock disconnects it mechanically from its power operating means.

In long distance missions, particularly in long range bombing missions, where maneuverability is not a requirement during flight to the objective but is highly important after arrival at the objective, it is current practice to provide a series of externally borne drop tanks, the fuel in which is preferably used first in getting to the objective and the drop tanks then discarded.

It is therefore another object of this invention to provide a series of drop tanks so mounted on the craft and so connected to the system and to each other that their fuel will be withdrawn uniformly, part out of each tank so as to maintain a balanced condition until the fuel in the drop tanks is exhausted.

Another object of the invention is to so construct, arrange, and connect the drop tanks that, with a single setting of the selector cock, which connects the main pump to the main tank, the entire contents of the drop tanks will be transferred to the main tank as fuel is being used out of the main tank.

Other objects and advantages will become evident as the invention is described in detail and reference is made to the drawing, wherein:

Fig. 1 is a schematic view of the complete system with its hydraulic and electrical connections.

Fig. 2 is an axial section through the jaw clutch through which power is applied to drive the automatic selector cock.

Figs. 3 and 4 are axial sections showing the closed and open positions, respectively, of a pressure sensitive switch which shows when a tank from which fuel is being taken is empty.

Figs. 5 and 6 are transverse sections showing the closed and open positions, respectively, of a manually openable switch for deenergizing a solenoid which, when energized, maintains power connection to the tank selector cock.

Figs. 7 and 8 show open and closed positions, respectively, of the piston valve which prevents operation of some of the functions of the system except when the engine is running.

Referring now to the drawing, an aircraft engine **10** carries a main fuel pump **12**, the pump being operatively connected to the engine to be driven thereby and adapted to supply fuel under pressure to the carburetor **14**, or like fuel metering device. The engine pump is provided with the customary relief valve whereby fuel is returned from the discharge side of the pump back to the intake side when the pressure at the discharge side exceeds a preselected value, which, for illustrative purposes may, in the instant case, be taken as fifteen pounds. It may preferably also be provided with a small adjustable leakage passage from the discharge side back to the intake. Such a leakage passage will return only a minute volume of fuel from the discharge side back to the intake side, but when the pump is pumping air only, will return a volume of air equal to substantially the entire air pumping capacity of the pump from the discharge side back to the intake side. The provision of the leakage opening therefore does not materially affect the capacity of the pump to raise the fuel pressure to the desired value, but insures that when the pump is pumping air no considerable air pressure may build up at the carburetor intake. The air eliminating feature of the engine pump is shown, described and claimed in my copending application Serial No. 570,938, filed January 1, 1945, now Patent No. 2,431,345, issued November 25, 1947.

A main tank **16** and an auxiliary tank **18** are carried within the aircraft as a permanent part thereof. The main tank **16** is so arranged that the reserve portion **17** of its contents which extends from the bottom to the line **19** may not be drawn from the tank except for emergency use until after the other portion **21** above the line **19** and all fuel in the other tanks has been used. A belly tank **20** and wing tanks **22** and **24** are carried externally on the underside of the fuselage and under the right and left wings respectively. The external tanks **20**, **22** and **24** may conveniently be referred to as the drop tanks.

A fuel cock **26** has seven equally spaced stations to which the pointer **28** may be turned, namely Off, B, L, R*i*, A, M, and R*e* when proceeding anticlockwise. These indicia, with the exception of Off show the stations of inflow into the selector cock.

A single outflow pipe **30** emerges from the center of the selector cock, flowing first through a strainer **32**, then through a pipe **33** to the suction side of the engine pump **12**. A pipe **34** connects the bottom of the belly tank **20** to the inflow station B, a branch **35** extending upward into the top of the tank **16**. A manual valve **31** in the branch **35** is normally closed. A pipe **36** connects the bottom of the left wing drop tank **22** to the inflow station L. A pipe **38** connects the bottom of the right wing drop tank **24** to the inflow station R*i*. A pipe **40** connects the bottom of the auxiliary tank **18** through an auxiliary pump **42**, which is driven by an electric motor **44**, to the inflow station A. An adjustable resistance **43** is employed to regulate the output pressure of the pump. A manual switch **45** is provided to disconnect the pump motor **44** from its current source. A pipe **46** connects the bottom of the main tank **16** through a pump **50** and branch pipe **48**, and the discharge side of the engine pump **12** through a pipe **53** and check valve **52**, to the inflow passages M and R*e*. A rotatable member of the selector cock **26** is secured to the pointer **28** for rotation therewith and this member is provided with a channel **55** for selectively or sequentially connecting the several inflow passages to the outflow pipe **30**. The pump **50** is driven by an electric motor **54**, and is so arranged and connected in the system that it may act as a booster pump, drawing from the main body of fuel **21** in tank **16** and delivering it to the suction side of the engine pump as an aid thereto, or it may operate as an emergency pump, drawing fuel from the reserve **17** and delivering it to the discharge side of the engine pump when, for any reason, the engine pump fails to maintain a predetermined pressure at the carburetor intake. Pump **50** is provided with an inbuilt relief valve which is set to maintain the pressure at its discharge side somewhat below that of the engine pump. For illustrative purposes the discharge pressure of pump **50** may be taken at twelve pounds.

As a means for sensing when the engine pump has failed to maintain a predetermined pressure at the carburetor intake, there is provided a fuel pressure sensitive electric switch **56** which is connected by a pipe **58** to the discharge side of the engine pump **12** and to the intake of the carburetor **14**. Switch **56** comprises a body in two parts, **60** and **61**, the interior being divided into two compartments, **65** and **67**, the lower compartments **65** being vented to the atmosphere at **63**. A spring-metal diaphragm **62** separates the compartments **65** and **67**, the diaphragm being slightly dished so that it will resist change in position from that shown in Fig. 3 to that shown in Fig. 4, or vice versa, with a resistance of approximately two pounds. The spring **64** is so proportioned that, in Fig. 3, it exerts an upward pressure of 11 and ⅜ pounds, and in Fig. 4, an upward pressure of 14 and ⅛ pounds. It follows that when the switch is closed as in Fig. 1, with the switch contacts **66** and **68** in engagement, there is a resistance to downward movement of 11 and ⅜ plus 2=13 and ⅜ pounds. Switch **56** will accordingly open if a pressure of 13 and ½ pounds is applied in the chamber **67**. Conversely, when the switch is open as in Fig. 4, with the switch contacts **66** and **68** separated, there is an upward pressure of 14 and ⅛ pounds −2 pounds=12 and ⅛ pounds A drop in pressure in the chamber **67** to 12 pounds will accordingly allow the switch to close. It will, of course, be understood that the pressures at

which the switch 56 changes from closed to open position and vice versa, are arbitrarily chosen for purposes of illustration and that any quick make and break pressure operated switch having an appropriate overlap between opening and closing pressure, so as to prevent hunting, will be considered within the scope of the invention. A warning signal light 70 is connected to the contact member 68 whereby the light comes on coincidentally with a drop in pressure sufficient to close the switch 56.

An electric motor 72 operates a vacuum pump 74 such as is commonly employed in an aicraft, the pump having its suction side 76 connected to the various vacuum operated instruments usually found on an aircraft and having the pressure side 78 connected by pipes 80, 82 and 84 to the tops of the drop tanks 22 and 24. A check valve 86 is interposed between the discharge side 78 and the pipe 80 and an air pressure regulator 88 is interposed between pipes 80 and 82. A gauge 90 gives visible indication of the air pressure being maintained. Pipes 92 and 94 connect the bottoms of the drop tanks 22 and 24 to the top of the drop tank 20, whereby, by maintaining a proper air pressure at the gauge 90, the fuel may be forced out of the drop tanks 22 and 24 into the drop tank 20, and out of the drop tank 20 into the pipe 34 from which it may be directed by way of station B of the selector cock 26 directly to the suction side of the engine pump 12, or, by opening the valve 31, through the main tank 16, pump 50, pipes 48 and 53 to the discharge side of the engine pump 12.

Weighted floats 96 and 98 operate conical valves 100 and 102 in tanks 22 and 24, whereby these tanks empty uniformly and maintain a balanced load on the wings, for, if one tank empties faster than the other, the greater height of the float in the fuller tank increases its outflow passageway through the conical valve of the fuller tank and thereby maintains the balance. When the tanks 22 and 24 have been emptied by air pressure as above described, the valves 100 and 102 should be closed except that there should either be a slight valve leakage in the closed position, or there should be separate leakage openings 101 and 103 so that air pressure coming into the tanks 22 and 24 after they are empty may get through into the tank 20 to pressurize the tank 20 when it is desirable to discharge its fuel in that manner.

A float 104 in the top of the main tank 16 operates a valve 106 to closed position to prevent fuel from the drop tanks entering the main tank 16 by way of the pipe 34 faster than it is being drawn from the bottom by the pump 50.

A float 108 operates an electric switch 110. When the level of the fuel in the main tank 16 falls below the line 19, the switch 110 closes, and thereafter the pump 50 cannot any longer act as a booster pump to deliver fuel from the main tank 16 by way of pipes 48 and 46, through station M of the selector cock, and by way of pipes 30 and 33 to the suction side of the engine pump 12, but can act as an emergency pump only to deliver the reserve fuel 17 by way of pipes 48 and 53 to the discharge side of the engine pump 12, and that only when the pressure in the pressure sensitive switch 56 drops below the predetermined value due to a tank from which the engine pump is taking fuel becoming empty. This is due to the fact that the electrical connection made by the switch 110 acts in conjunction with another switch hereinafter described to prevent the motor driven selector

cock 26 remaining on either of the positions M, Re, or Off.

The selector cock pointer 28 and the member which carries the channel 55 which selectively or sequentially connects the inflow positions B, L, Ri, A, M and Re to the outflow pipe 30, are both secured to the cam shaft 112 to rotate therewith. Also fast on the cam shaft 112 is a cam 114 which has as many notches 116 in its periphery as the selector cock 26 has stations, which is in the instant embodiment is seven. A switch 118 is always open as shown whenever the free end of the operating arm 120 has dropped into one of the notches 116.

Four cams 122, 124, 126 and 128, also fast on the cam shaft 112, are provided for closing the switches A, M, Re and C respectively, the operating lugs on the cams 122, 124 and 126 being so positioned that the switches A, M and Re close only when selector cock pointer is set on A, M or Re respectively, while the lug on the cam 128 is so made as to keep the switch marked C closed when the selector cock pointer is on either M or Re or Off, and open on all other stations.

A disc 132*a* (see Figs. 1 and 2) is fast on the rear end of the cam shaft 112. Disc 132*a* and a second disc 132 are joined together at the edges by a yoke 144. A tubular part 134 extends rearwardly from the disc 132 and carries a toothed clutch part 137 at the free end. A switch 136 is operable by a plunger 131 (see Figs. 5 and 6) which lies between the discs 132*a* and 132. Plunger 131 is slidable radially between the discs and between the guide lugs 139 which also join one disc to the other. A contact member 138 extends laterally from the plunger 131 which is normally held in contact with the contact member 140 by a spring 142 as seen in Fig. 5. A small cam 130 is fast on the forward end of a shaft 135 and lies between the discs 132*a* and 132. Cam 130 has a single V notch 143 (see Fig. 6) into which the V end of the plunger 131 is held by the spring 142 when the switch is closed as in Fig. 5. Rotation of the cam 130 by the shaft 135 in either direction will raise the plunger 131 and open the switch 136 as seen in Fig. 6. The yoke 144 terminates in a stop 145 (see Fig. 5) which prevents the plunger 131 ever rising high enough to get wholly out of the notch 143. It will be understood that the discs 132*a* and 132 with their connecting yoke 144 always rotate with the shafts 112 and 135.

A gear 146 has a prolonged tubular hub 148 with a flange 150. An electric motor 151 has an inbuilt high reduction gear box 153 through which a pinion 155 is driven, the pinion being in constant mesh with the gear 146. A spring 152 reacts against a stationary part 154 of the structure to move the flange 150 into engagement with the stop 156. A solenoid coil 158 receives electric current through the switch 136 and, when energized, moves the hub 148 in the direction of the arrow 160, whereby the toothed clutch 162, which has one toothed part 137 on the tubular end 134 and the other toothed part 139 on the gear 146, will be engaged, and the switch 165 as well as the jaw clutch 162 will be closed. Switch 165 is connected in series with the time delay switch 118, whereby, when the engine pump 12 restores the interrupted pressure in the fuel pressure sensitive switch 56, which thereby cuts the direct line to the motor 151, current will nevertheless be maintained at the motor terminal through the switches 118 and 165 as long as the pointer 28 is intermediate two stations. A selector handle

164 is fast on the outer end of the shaft 135. A grooved collar 166 fast on the shaft 135 is engaged by a stationary part 168 to allow rotation but prevent axial movement of the shaft. Inasmuch as the frictional resistance to rotation of the selector cock 26 must be overcome by the handle 164 when manual operation of the selector cock is being effected, it follows that, as soon as a slight torque is manually applied to the handle 164, to turn the cam 130 the switch 136 opens as in Fig. 6, the coil 158 is thereby deenergized, the clutch 162 is disengaged by the spring 152 and the switch 165 is coincidentally opened, whereby the motor 151 need not be manually rotated through the high reduction gearing each time the selector cock is manually operated.

Since it is desirable that certain parts of the fuel system should not become operative except when the engine is running, there is provided a switch mechanism 170 which is responsive to the oil pressure of the engine lubricating system. Switch 170 comprises a contact bar 172 movable by a piston 174 into engagement with contacts 176 and 178, which are in turn separately movable into contact with the bar 172 by the manually operable handles 180 and 182. The cylinder 184 within which the piston 174 is slidable is connected by a pipe 186 to the oiling system of the engine 10. A spring 188 urges the switch 170 to its open position. In order to provide a suitable overlap as between opening and closing of the switch 170 to prevent hunting, a detent ball 191 is radially slidable in a pocket 193 in a boss 185 of the cylinder 184 and is urged inward by a spring 195 into a notch 197 when the switch is open as in Fig. 7 and into a notch 199 when the switch is closed as in Fig. 8. The slopes of the notches 197 and 199, and the strength of the spring 195 are in such proportion that, when no pressure exists in the pipe 186, a force of 2 pounds will be required to move the piston 174 from right to left just before the ball 191 passes the point 187 and 3 pounds to move it from left to right, also just before it passes the point 187. The spring 188 is then so proportioned that it will be offering a resistance to movement from right to left of 17 pounds just before the ball passes the point 187 and will be exerting a force of 19 pounds to move the piston from left to right also just before the ball passes the point 187. Obviously, it will take 17+2=19 pounds oil pressure to move the piston left until the point 187 passes the ball 191 to close the switch, and, when the pressure in the pipe drops to 16 pounds, the 19 pound force exerted by the spring 188 minus the 3 pounds resistance caused by the spring 195 will again open the switch. An oil pressure gauge 189 shows when the pressure is being maintained at the desired value. A switch 190 is closable by the solenoid coil 192. A main switch 194 connects the battery 196 or other source of electric current to the system.

The operation of the system is substantially as follows:

Operation

Let it be assumed that the engine together with the entire fuel system has been at rest long enough to allow the pressure at the carburetor 14 to drop low enough to cause the pressure responsive switch 56 to close as seen in the drawing, and that the fuel cock pointer 28 is at the Off position and the main manual switch 194 is open as shown.

By closing the switch 194 current will be supplied by way of the now closed fuel pressure responsive switch 56 to the relay coil 192 thereby closing the switch 190 through which an electric current is directed to the motor 50 which pumps to the discharge side of the engine pump 12 and to the carburetor 14 and the pressure responsive switch 56. Switch 56, however, remains closed because the relief valve of the pump 50 is set at twelve lbs. pressure while thirteen and one-half lbs. pressure is required to open the switch 56.

While this twelve lbs. pressure is being maintained, the engine may be started in the usual manner. When the engine starts, the engine pump cannot instantly obtain fuel because the selector cock is on the Off position. In a matter of several seconds, however, the engine oil pressure becomes high enough to close the oil pressure switch 170 whereupon electric current reaches the selector cock operating motor 151 and the solenoid coil 158 simultaneously, thereby engaging the clutch 162 and rotating the shaft 112 to turn the selector cock pointer 55 anticlockwise. When the pointer reaches the B position, the suction side of the engine pump 12 is hydraulically connected to the bottom of the drop tank 20 and may therefore increase the pressure at the carburetor from twelve to fifteen lbs., which will open the fuel pressure sensitive switch 56 and thereby stop the selector cock motor 151, disengage the clutch 162 and open the switch 190 to stop the motor 54 of the pump 50. Thereafter the fuel cock pointer 28 will remain at station B until the drop tank 20 has been pumped empty by the engine pump 12.

When the drop tank 20 is empty, air will be drawn therefrom by the engine pump 12 and discharged into the pipe 58 whereupon the pressure responsive switch 56 will close again and electric current will be directed simultaneously through the switch 190 to the motor 54 of the pump 50, through the selector cock motor 151 and through the solenoid coil 158 to engage the clutch 162 to move the fuel cock pointer 28 from station B to station L.

Between the time the selector cock leaves the station B and the time it reaches the station L, the suction side of the engine pump is disconnected from all fuel sources, and cannot therefore build up pressure to open the pressure sensitive switch 56, so that the pump 50 must continue to provide the twelve pounds pressure at the carburetor intake all the while the selector cock motor 151 is turning the pointer from station B to L. It is noted, however, that there is a possibility that the pressure at the pressure sensitive switch 56 might be built to fifteen lbs., and the switch opened while the pointer was intermediate the stations B and L and the selector cock motor thereby stopped short of its objective. Such a condition could develop if the relief valve in the motor pump 50 should stick slightly for several seconds only and build the carburetor pressure to fifteen instead of twelve pounds while the pointer 28 was moving and was intermediate two stations. In such an event, however, the time delay switch 118 would function to prevent stopping between stations, for it will be seen that, as soon as the pointer 28 moves several degrees away from any station, the time delay switch 118 is closed and does not open again until the pointer is within several degrees from the next station. It is further noted that while the selector cock motor 151 is started by current received through a closed pressure responsive switch 56 upon pressure failure therein, it is kept operative until the next station is reached irrespective of whether the

pressure is built up and the switch 56 opened or not, because the time delay switch receives current directly from the battery and directs it through the switch 165 to the selector cock motor 151 and to the solenoid coil 158 which closes the switch 165 as well as engages the clutch 162. Obviously then, when the pointer once leaves a station it cannot stop short of the next station. The cycle of operations which shifted the selector cock from B to L upon the drop tank 20 becoming empty is repeated to shift it from L to Rt when the drop tank 22 becomes empty, and is again repeated to shift from Rt to A when the drop tank 24 becomes empty. The mechanism whereby the three drop tanks 20, 22 and 24 are now released and discarded is not shown.

It is noted that up to this point fuel has been taken only from the drop tanks, and that it came from the tanks directly to the intake side of the engine pump without the assistance of a booster pump. This procedure is quite satisfactory since flying during this period is for the most part at low altitude. However, if it becomes necessary to go to a relatively higher altitude while the drop tanks have not yet been emptied, resort is had to pressurizing the drop tanks by the motor driven air pump 74 which is used also at low altitudes under certain conditions hereinafter to be described. The air pressure regulator 88 may be set to zero when it is undesirable to pressurize the drop tanks. However, when the drop tanks are emptied, and station A is reached by the selector cock pointer 28, hydraulic connection is made from the permanent auxiliary tank 18 through the booster pump 42, whereby fuel from the tank 18 reaches the suction side of the engine pump at a considerably increased pressure.

Coincidentally with the making of hydraulic connection from the auxiliary tank 18 through the booster pump 42 and station A of the selector cock 26, the cam 122 closes the switch A and provides current to the booster pump motor 44 throughout the emptying of the auxiliary tank 18. When the auxiliary tank 18 is empty the same failure of pressure at the pressure responsive switch 56 moves the selector cock pointer 28 from station A to station M, whereby the cam 122 opens the switch A and the cam 124 closes the switch M.

The closing of the switch M brings current from the battery 196 to the motor 54 of the pump 50 irrespective of whether the pressure responsive switch 56, the relay switch 190, or the oil pressure switch 170 are open or closed, whereby the pump 50 will act as a booster pump and draw fuel from the main tank 16 and deliver it to the suction side of the engine pump 12 until the level of the fuel drops below the line 19, whereupon the float operated switch 110 will close and light the warning signal 70.

Current may now reach the selector cock operating motor 151 for rotating the selector cock 26 through the float switch 110 and the fully closed oil pressure switch 170, and will rotate the selector cock anticlockwise. During movement between stations the flow of fuel past the fuel cock 26 to the suction side of the engine pump is of course interrupted, and the pressure responsive switch 56 closes momentarily between each station. When the pointer passes Re the suction side of the engine pump may momentarily get fuel from the reserve 17 and will therefore open the pressure responsive switch 56 which normally controls the selector cock motor 151. But this time the opening of the switch 56 will not stop the motor 151 for it is now receiving current independently of the switch 56 through the reserve float switch 110.

Now inasmuch as, in the operation of the system above described, all other tanks were emptied before connection was made to the reserve supply 17, the selector cock will continue to rotate round and round until the operator observes that the warning light continues to be lit. He then manually operates the handles 180 and 182 of the oil pressure switch 170 so as to withdraw the contact members 176 and 178, whereupon no electrical connection will exist to the selector motor 151. The operator may now manually place the selector pointer 28 on station Re whereupon current will flow from the battery through the cam operated switch Re to energize the coil 192 and close the switch 190 whereupon current will flow to the motor 54 of pump 50 and fuel will be pumped from the reserve 17 to the suction side of the engine pump 12.

In the foregoing description of the operation of subject fuel system it was assumed that at the start the pointer 28 was at the Off station and that the entire system was permitted to function automatically thereby emptying the tanks in their normal anticlockwise sequence. It may happen, however, that the pointer may have been inadvertently or intentionally placed at a different station, as for example on station A.

The carburetor may now be primed, if necessary, by means of the pump 50 as hereinbefore described. When the engine is started, the fuel pressure sensitive switch 56 will still be closed whereby the selector cock motor will attempt to rotate the selector cock away from the A station, but before it can move it as much as the several degrees necessary to close the delaying switch 118, the engine pump will have raised the pressure at the carburetor enough to open the pressure sensitive switch 56, after which fuel will be taken from the auxiliary tank 18 through the station A until this tank is empty.

The closing of the pressure sensitive switch 56 due to this empty tank condition will start the selector motor 151 which will move the pointer 28 to station M, whereby it may take fuel from main tank 16 down to the line 19 whereupon the float switch 110 is closed and will therefore operate in conjunction with the fully closed oil pressure operated switch 170 to maintain connection to the selector motor 151 independently of the pressure sensitive switch 56.

The selector cock will therefore rotate anticlockwise round and round until the pilot observes the continued operation of the signal 70 whereupon he may operate the handle 180 of the oil pressure switch 170 thereby withdrawing the contact 176 from the contact 172, and the pointer will stop, except that because of the cam switch C, it cannot stop on station M, Re or Off, and because of the time delay switch 118 it cannot stop between stations.

If the pilot now stops rotation of the selector with the pointer at station B, he may use all of the fuel in the three drop tanks without further change of stations after which the warning light 70 will indicate to him that he should now shift to station Re and use the reserve supply 17.

If the pilot desires, he may operate the system by opening the oil pressure switch 170 so as to eliminate the selector motor 151 altogether, then open the valve 31 and set the pointer at station A and use the fuel from auxiliary tank 18 first,

then when the warning light 70 indicates an empty tank, shift the selector cock manually to station M. The booster pump 50 will act as an emergency pump to pump to the discharge side of the engine pump and thereby maintain pressure at the carburetor until the shift has been made, whereupon the signal light 70 will go out and the pressure sensitive switch 56 will open.

Opening of the pressure sensitive switch 56, however, does not stop the motor 54 of the pump 50 for the reason that the motor 54 now receives current by way of the cam operated switch M. The pump 50 therefore now takes fuel from the main tank 16, pumps it through the pipe 46 through the selector cock 26, pipes 30 and 33 to the suction side of the engine pump 12 which in turn raises the pressure still further at the carburetor. Since the drop tanks are pressurized and the hand valve 31 is open, the entire remaining supply of fuel will pass from the drop tanks through the main tank and from the main tank to the suction side of the engine pump, the float valve 106 in the meantime preventing inflow into the tank 16 faster than it is being used therefrom.

Still another procedure in operating the system may be carried out as follows:

By placing the selector cock on station A, opening the hand valve 31 and the oil pressure responsive switch 170, the fuel in the auxiliary tank 18 will first be pumped to the suction side of the engine pump, the engine pump raising it to a slightly higher pressure at the carburetor. When tank 18 is empty, the pressure sensitive switch 56 will close, which will coincidentally close the switch 190 whereby current will be directed to the motor 54 of the pump 50.

Now the pump 50 cannot pump through pipe 46 because the selector cock is on station A, so it pumps to the discharge side of the engine pump through pipe 53. Since the drop tanks are pressurized and the hand valve 31 is open, the entire fuel supply is used with the single setting on station A. It is noted that with this method of operation the engine pump is used only while the auxiliary tank 18 is being pumped out.

Having described my invention and several ways in which it may be operated, I claim:

1. In an aircraft fuel system a plurality of fuel tanks, a fuel pump, a selector cock having a station for each tank, adapted for connecting the respective tanks one at a time to the suction side of said pump, electric power means for rotating said selector cock from one station to the next, a pressure sensitive device at the discharge side of said pump adapted for directing an electric current to said electric power means for rotating said electric power means to rotate said selector cock away from any station when the pressure at said discharge side drops due to said station having said suction side connected to an empty tank, and a float operated switch means in one of said tanks adapted when the fuel in said tank falls below a predetermined level to direct an electric current to said electric power means to start said electric power means irrespective of said pressure sensitive device to rotate said selector cock.

2. In an aircraft fuel system a plurality of fuel tanks, a fuel pump, a selector cock having a station for each tank adapted for connecting the respective tanks one at a time to the suction side of said pump, electric power means for rotating said selector cock from one station to the next, a pressure sensitive switch at the discharge side of said pump adapted for directing an electric current to said electric power means for rotating said electric power means to rotate said selector cock away from any station when the pressure at said discharge side drops due to said station having said suction side connected to an empty tank, and a float operated switch in one of said tanks adapted when the fuel in said tank falls to a predetermined level to direct an electric current to said electric power means to operate said electric power means irrespective of said pressure sensitive device to rotate said selector cock.

3. In an aircraft fuel system a plurality of fuel tanks, a fuel pump, a selector cock having a station for each tank adapted for connecting the respective tanks one at a time to the suction side of said pump, power operated means for rotating said selector cock from one station to the next, a pressure sensitive device at the discharge side of said pump adapted for connecting a source of power to said power operated means for rotating said power operated means to rotate said selector cock away from any station when the pressure at said discharge side drops due to said station having said suction side connected to an empty tank, and a float operated means in one of said tanks adapted when the fuel in said tank falls to a predetermined level to apply said source of power to said power operated means to thereby start said power operated means, irrespective of said pressure sensitive device, to rotate said selector cock, a cam operated means rotatable in coincidence with said selector cock and having operating surfaces adapted when operative to stop rotation of said selector cock at a predetermined series of stations only, and a manual means for making said cam operated means effective.

4. In an aircraft fuel system a plurality of fuel tanks, a fuel pump, a selector cock having a station for each tank adapted for connecting the respective tanks one at a time to the suction side of said pump, electric power means for rotating said selector cock from one station to the next, a pressure sensitive switch at the discharge side of said pump adapted for directing an electric current to said electric power means for rotating said electric power means to rotate said selector cock away from any station when the pressure at said discharge side drops due to said station having said suction side connected to an empty tank, and a float operated electric switch in one of said tanks adapted when the fuel in said tank falls to a predetermined level to direct an electric current to said electric power means to operate said electric power means, irrespective of said pressure sensitive device, to rotate said selector cock, electrically conductive means extending from said pressure sensitive electric switch and said float operated electric switch to said electric power means, a cam rotatable by said selector cock, said cam having operating surfaces corresponding to a selected series of stations on said selector cock, an electric switch actuated by said operating surfaces, and a manually operable switch means operative to open the direct circuit extending from the fuel pressure sensitive switch and the float operated electric switch to said electric power means, and operative to complete a circuit trrough said cam operated switch in series, whereby said selector cock will stop only at the stations of said selected series.

5. In a fuel system having a plurality of tanks, a tank selector cock having a station for each

tank, a fuel pressure pump, an electric motor for rotating said selector cock from one station to the next, a pressure sensitive switch operative to close and to direct current to said motor when said selector cock has said pump connected to an empty tank, a delaying switch operative to open when said selector cock is turned to any station and to be closed when it is moving from any station to the next, a clutch for drivably connecting said selector cock to said motor, a magnetically operable switch, electromagnetic means for coincidentally engaging said clutch and closing said switch and conductors forming a series circuit through said pressure sensitive switch and said delaying switch, or through said electromagnetic operable switch and said delaying switch when said pressure sensitive switch is open.

6. The structure defined in claim 5 with a manual means for rotating said selector cock, a torque sensitive coupling the driving and driven parts of which are rotatably yieldable to the application of opposite torques thereto interposed between said manual means and said selector cock, a torque sensitive electric switch openable by the yielding of said coupling upon application of a torque to said manual means, and conducting lines extending to said electromagnetic means openable by said torque sensitive switch whereby manual operation of said selector cock disengages said electromagnetic means and thereby disengages said clutch.

7. In an aircraft fuel system, a plurality of fuel tanks, a fuel pump, a rotatable selector cock having a station for each tank adapted for connecting the respective tanks one at a time to the suction side of said pump, an electric motor for rotating said selector cock from one station to the next, a fuel pressure operated electric switch at the discharge side of said pump closable for conveying an electric current to said motor for rotating said selector cock away from any station when the pressure at the discharge side drops due to said station having said suction side connected to an empty tank, a float operated electric switch associated with one of said tanks closable for conveying an electric current to said motor independently of said fuel pressure sensitive switch for rotating said motor when the fuel in said tank falls below a predetermined level, an oil pressure operated electric switch, normally closed when said engine is in operation for directing current so said electric motor and a cam operated electric switch including an operating cam on said rotatable selector cock, said cam having switch closing lobes at a preselected part of its periphery, parallel electrical conductors extending from a current source through said fuel pressure operated electric switch and said float operated electric switch joined into a single conductor which extends through said oil pressure operated electric switch to said motor, a branch circuit extending from said oil pressure operated electric switch through said cam operated electric switch to said motor, and manually operable means associated with said oil pressure operated electric switch for opening the circuit through the said single conductor and completing a circuit through said cam operated switch.

8. In the old combination of a device including a shaft and actuating means for rotating said shaft manually or by power, an improvement in the actuating means which comprises a rotatable switch support fast on said shaft, an electric switch on said support, a switch spring for maintaining said switch in closed position, a power rotated member, a manually rotatable member, a cam on said manually rotatable member adjacent said switch, operative upon either a gain or a loss of rotative movement of the manual means with respect to the switch support to open said switch against the resistance of said switch spring, means to limit to part of a turn the degree of rotative movement of the cam with respect to the switch support, a clutch part on the manually rotatable member, a complementary clutch part on the power driven member, a clutch disengaging spring, and an electromagnetic device for engaging said clutch parts deenergized by the opening of said switch by operation of said manual means to allow said clutch disengaging spring to disengage said clutch parts for manual operation.

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