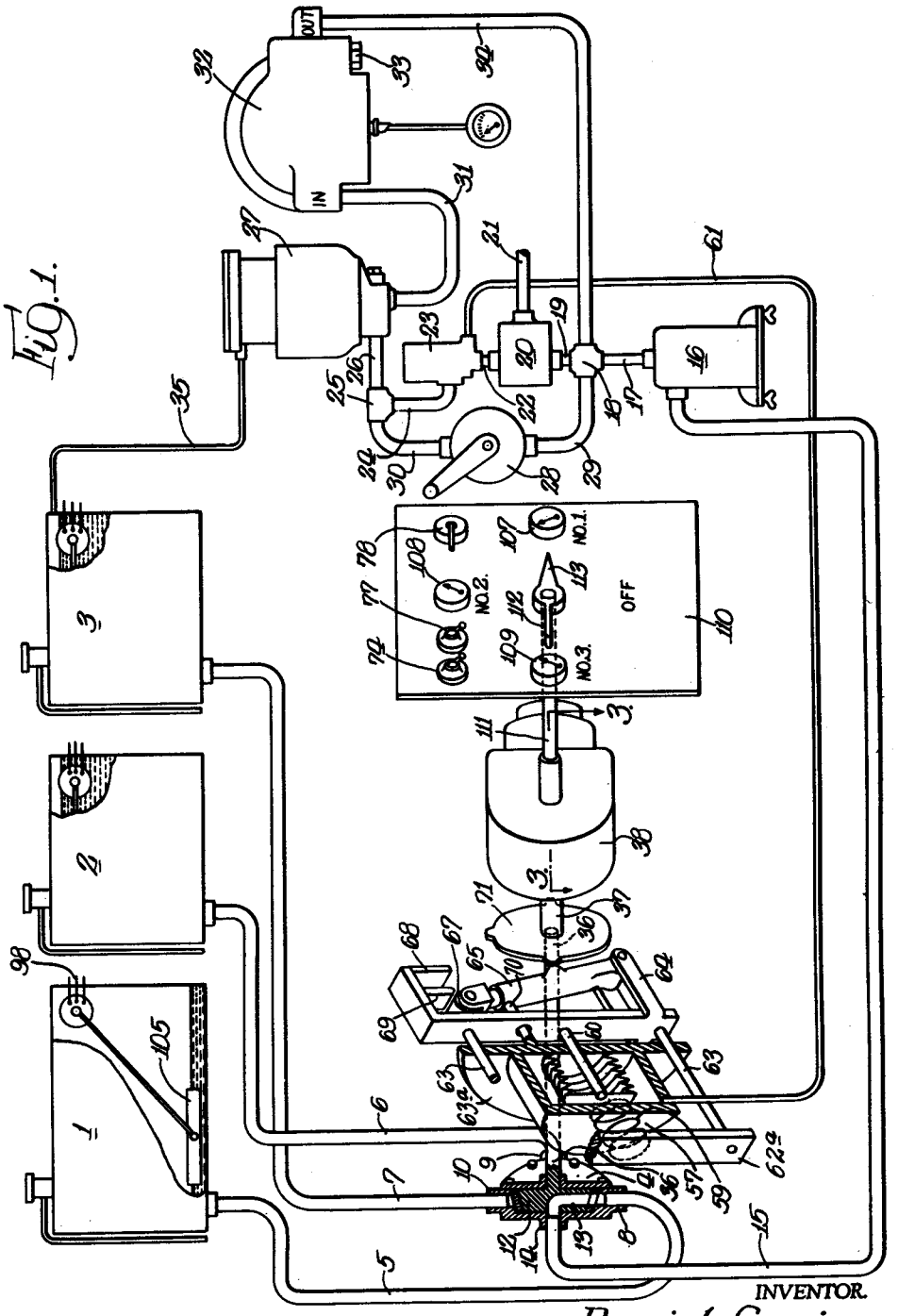
March 30, 1943. D. SAMIRAN 2,314,899

FUEL SYSTEM INCLUDING TIME DELAYED SELECTOR VALVES

Original Filed March 13, 1939 3 Sheets-Sheet 1

Fig. 1.



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FUEL SYSTEM INCLUDING TIME DELAYED SELECTOR VALVES

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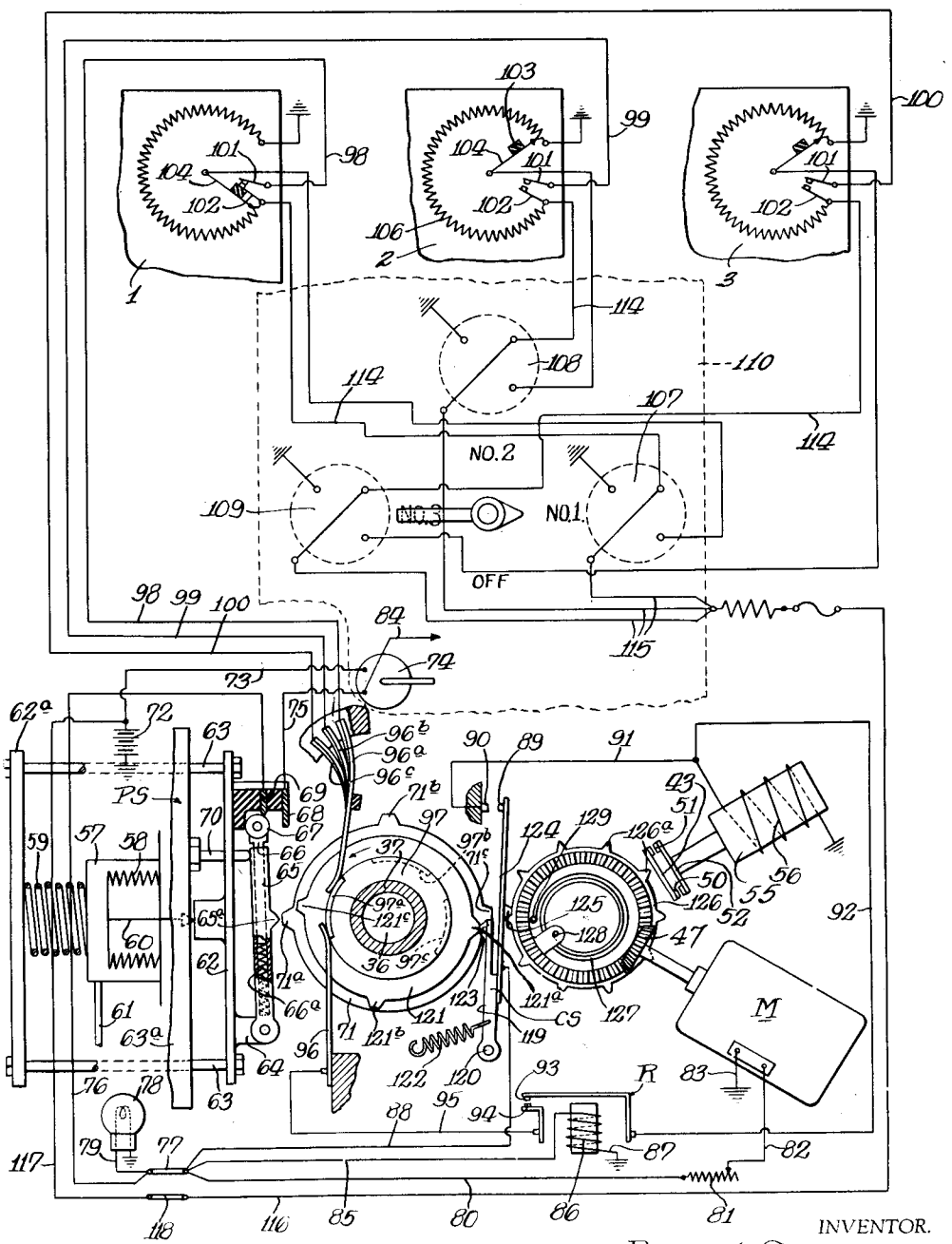
Fig. 2.



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FUEL SYSTEM INCLUDING TIME DELAYED SELECTOR VALVES

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Fig. 3.

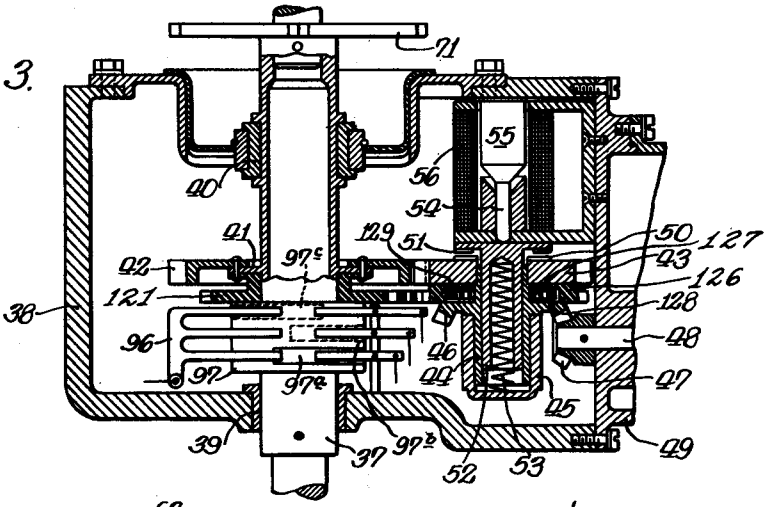


Fig. 4.

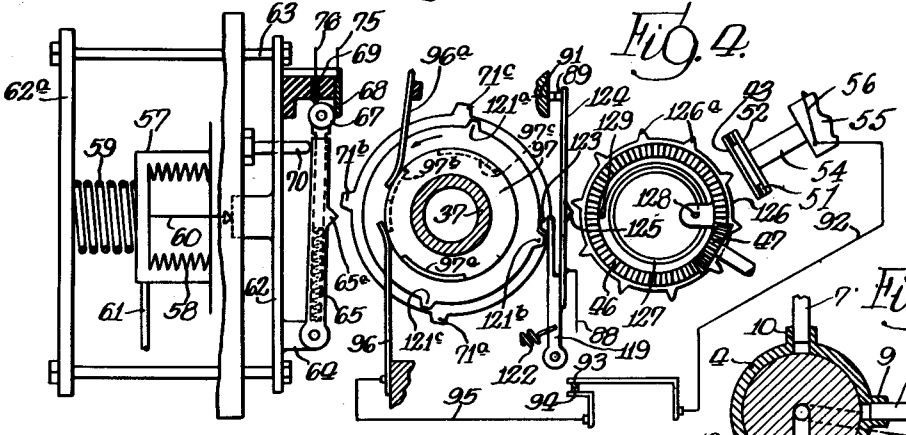
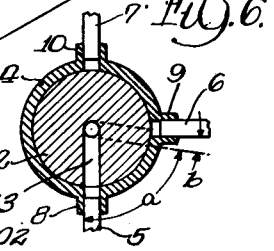


Fig. 6.



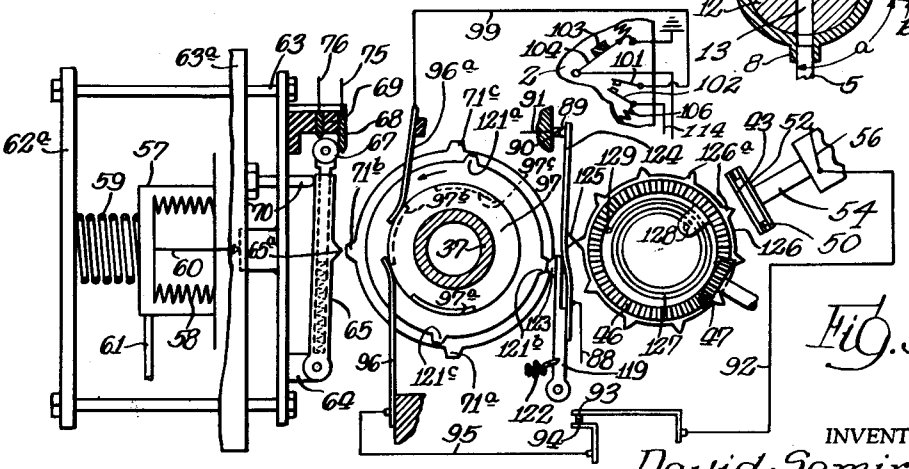


Fig. 5.

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UNITED STATES PATENT OFFICE

2,314,899

FUEL SYSTEM INCLUDING TIME DELAYED SELECTOR VALVES

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Original application March 13, 1939, Serial No. 261,542. Divided and this application August 13, 1940, Serial No. 352,427

20 Claims. (Cl. 158—36)

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

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.

The present invention relates in general to fuel systems wherein a plurality of individual fuel sources such as tanks or containers are automatically or manually connected in a predetermined order to a source of fuel consumption such as an airplane engine or the like.

The present application is a division of my co-pending application, Serial No. 261,542, filed March 13, 1939.

In those types of fuel systems which have selector valves operated by electric motors or the like, and where such operation is initiated by a fuel pressure failure switch, it is desirable to have the valve operate quickly from one position to its next position. Provision must be made, however, for a time period of delay to give time for the fuel pressure failure switch to respond properly to fuel pressure failure after the valve has been shifted to a new position and thereby subsequently control initiation of operation of the selector valve motor when fuel pressure again fails.

It is therefore an object of my present invention to provide a selector valve operating mechanism wherein the motor for operating the selector valve may be normally operated at high speed from one position to the next, thereby minimizing the period of time between successive selector valve positions, and to provide a delayed period of time after port registration position has been attained during which time period the mechanism that is responsive to the pressure of fuel from the pump can function as desired for the purpose of eventually accomplishing another cycle of operation of the selector valve immediately upon a call for such. By this arrangement, if there is fuel in the tank with which the selector valve has just been connected, the selector valve is retained in its new position. In case such tank is empty as a result of a bullet hole leak or other cause, the fuel pressure responsive means may have time to respond to such condition and thereafter effect movement of the selector valve on to the next successive position.

A further object is to provide means in the form of an electrically operated clutch mechanism to effect exact registration of the selector valve ports, thereby eliminating the possibility of port overrun resulting from momentum of the motor after it is de-energized as in installations where such clutch is not provided.

Still a further object is to provide, in connection with a motor operated selector valve wherein the motor is controlled by a fuel pressure responsive switch, a means to stop the selector valve at the completion of its operation through the medium of a solenoid or the like for operating the clutch and to provide a clutch switch for controlling the solenoid which has cooperating with it a tripping cam including a resilient connection in which energy is built up to a predetermined point, during which energy build-up the clutch is inoperative, and at the completion of the build-up of energy the amount of energy is sufficient to close the clutch switch, thereby causing the selector valve to start rotating, the clutch switch cooperating with a clutch switch cam of the selector valve shaft to effect continuation of such closure of the clutch switch until the next succeeding port alignment position of the selector valve is assumed.

Still another object is to provide, in connection with the selector valve shaft, a commutator arrangement for also controlling the clutch solenoid, the various fuel tanks being provided with float operated switches which in conjunction with the commutator control the clutch solenoid to effect a de-energization thereof after a cycle of operation of the selector valve has been completed, providing the tank last connected with the selector valve contains fuel. If such tank is empty, the mechanism thereby effects a movement of the selector valve to the next position corresponding to a tank containing fuel.

Still a further object is to provide a selector valve operating system wherein normal rotation of the selector valve is at relatively high speed, but a time delay of the valve at port registration position is effected by control of a clutch, the clutch in turn being under control of a winding spring which permits a degree of lost motion between a motor that is continuously operative during both a selector valve movement period and its time delay period.

In addition to the foregoing objects and advantages particularly pointed out by my invention, others will become apparent from the following description taken in connection with the appended drawings, it being clearly understood that the following description as well as the drawings are for purposes of illustration and example only and are not to be taken as in any way limiting the spirit and scope of my invention. Instead the spirit and scope thereof are to be limited only by the prior art and by the terms of the appended claims.

Referring now to the drawings, wherein like characters designate similar parts throughout the several views—

Figure 1 is a diagrammatic representation of a fuel system including a time delayed selector valve embodying my invention;

Figure 2 is a diagrammatic view particularly of the fuel gauges and controlling mechanism for the selector valve of my system, the parts being shown in normal position;

Figure 3 is a sectional view as on the line 3—3 of Figure 1 showing details of construction of the parts illustrated diagrammatically in the lower half of Figure 2;

Figure 4 is a view similar to a portion of Figure 2 showing the parts in a position assumed as a result of fuel pressure failure and resultant operation of the selector valve through a cycle of operation (nearly completed);

Figure 5 is a similar view showing the position of the parts assumed when there is fuel pressure failure from causes other than an empty tank, and

Figure 6 is a sectional view through the selector valve and illustrating certain positions thereof.

In the accompanying drawings I have used the reference characters 1, 2 and 3 to indicate fuel tanks. Although three tanks are shown, obviously a greater or less number may be provided without departing from the spirit of my invention. Only three tanks are shown in order to simplify the drawings.

The fuel tanks 1, 2 and 3 are piped to a selector valve 4 as by pipes 5, 6 and 7 entering bosses 8, 9 and 10 of the selector valve. The selector valve has a rotatable valve plug 12 provided with an L-shaped passageway 13 adapted to selectively connect the inlet bosses 8, 9 and 10 with an outlet boss 14.

The outlet boss 14 has a fuel pipe 15 connected therewith and extending to a fuel strainer 16. The strainer 16 has an outlet pipe 17 connected through a cross fitting 18 and a pipe 19 to an engine driven fuel pump 20. The shaft of the pump 20 is indicated at 21 and may be suitably connected with the airplane engine.

An outlet pipe 22 from the pump 20 connects with a switch pressure regulator 23. The fuel outlet of the regulator 23 is connected by a pipe 24, a T-fitting 25 and a pipe 26 to an air-vapor eliminator 27. A wobble pump 28 shunts the fuel pump 20 and the pressure switch regulator 23. The inlet pipe 29 and the outlet pipe 30 of the wobble pump 28 are connected with the cross fitting 18 and the T-fitting 25 to accomplish this purpose.

The air-vapor eliminator 27 has a fuel pipe 31 connected with its outlet and with the inlet of a fuel injector 32. The fuel injector 32 includes a pressure relief valve 33 through which fuel in excess of the requirements of the injector 23 is returned through a pipe 34 to the cross fitting 18 and thereby the inlet of the pump 20. The air-vapor eliminator 27 has an air-vapor outlet 35 for discharging air and vapor eliminated from the fuel within the eliminator 27. Such air and vapor are returned to one of the tanks, for instance 3, thereby permitting any fuel condensing from the vapor to return to the fuel supply.

The switch pressure regulator 23 and the air-vapor eliminator 27 are described in my co-pending application above referred to and form no part of my present invention but are illustrated merely to show how the present fuel system may be connected with an engine or other fuel consuming device. In some types of engines a carburetor would be substituted for the fuel injector 32.

For operating the selector valve 4 I provide a shaft 36. The shaft 36 is connected with an extension shaft 37 extending into a housing 38. The extension shaft 37 is journalled in bearings 39 and 40 of the housing 38. Within the housing 38 and secured to a flange 41 of the extension shaft 37 is a driven gear 42. The gear 42 meshes with a driving gear 43 which in turn is loosely journalled on a sleeve 44. The sleeve 44 is rotatable in a bearing 45 fixed in the housing 38 and is provided with beveled gear teeth 46. A bevel pinion 47 continuously meshes with the teeth 46 and is mounted on a shaft 48. The shaft 48 is driven by a motor M through suitable step-down gearing (not illustrated). The motor M is mounted in a housing 49 extending from the housing 38.

The back of the driving gear 43 is provided with serrations or clutch teeth 50 with which companion serrations or clutch teeth 51 are at times adapted to coact. The clutch teeth 51 are formed on a sleeve 52 slidably and non-rotatably mounted in the sleeve 44 and normally urged to clutch disengaging position by a spring 53.

For engaging the clutch teeth 50 and 51 with each other I provide a stem 54 engaging the sleeve 52 in opposition to the spring 53 and formed as an extension of a solenoid plunger 55. The plunger 55 is so located in a solenoid coil 56 that upon energization of the coil the plunger 55 will be drawn into it and engage the clutch teeth 51 with the clutch teeth 50. Thereupon the driving gear 43 will be rotated from the bevel gear 46 which, as will hereinafter appear, is rotating at any time it is possible to energize the solenoid coil 56.

For controlling the motor M I provide a fuel pressure responsive switch PS which is fully described in my above referred to co-pending application. Briefly, the switch PS has a bellows chamber 57 in which is mounted a collapsible bellows 58. The bellows 58, when collapsed by pressure in the chamber 57 against the tension of a spring 59, actuates a stem 60 in a right hand direction. A conduit 61 extends from the bellows chamber 57 to the switch pressure regulator 23 which regulator furnishes a substantially constant fuel pressure to the conduit 61 as long as the pump 20 is receiving a predetermined quantity of fuel or fuel in excess of such quantity. When the pump 20 runs out of fuel, then the pressure within the bellows chamber 57 drops so that the spring 59 retracts the stem 60.

Whenever the bellows is collapsed by suitable fuel pressure acting thereon within the bellows chamber 57, the stem 60 moves a switch carriage consisting of supporting bars 62 and 62*a* and a pair of sliding guide rods 63 therefore in a right hand or outward direction, as in Figure 2. The rods 63 slide in a stationary support 63*a*. The supporting bar 62 has a pair of ears 64 to which is pivoted a switch arm 65 having a telescoping extension 66 biased outwardly by a spring 66*a*. The extension 66 carries a metallic contact roller 67 adapted at times to bridge a pair of contacts 68 and 69 as shown in Figures 4 and 5. The roller 67 and the contacts 68 and 69 are suitably insulated from the remaining parts of the pressure switch PS.

When the fuel pressure drops within the bellows chamber 57 the switch carriage 62—62*a*—63 will be moved in a left hand direction by the

spring 59 whereupon closure of the circuit across the contacts 68 and 69 is effected, as illustrated in Figure 4. Such closure of the contacts results from the receding carriage bar 62 carrying with it the switch arm 65 and the arm in turn engaging a stationary stud 70. Such engagement causes the roller 67 to move outwardly across the edge of the contact 69 and eventually bridge this contact and the contact 68.

The position of the pressure switch PS is such that outward movement of the carriage 62—62a—63 from the position of Figure 4 to the position of Figure 2 will open the circuit through the switch by engagement of a cam lobe 65a thereof with a lobe of a cam 71 located on the selector valve shaft 36. The pressure switch cam 71 has three such lobes (71a, 71b and 71c corresponding to the tanks 1, 2 and 3, respectively). In the position of Figure 4 it will be obvious that slight further counterclockwise rotation of the cam 71 will cause the lobe 71b to register with the switch arm lobe 65a, thereby effecting such opening of the circuit through the pressure switch PS upon subsequent build-up of pressure in the chamber 57.

As previously stated, the switch PS is provided for controlling the motor M. The circuit for this purpose includes a source of current supply such as a battery 72 having one side grounded and the other side connected through a wire 73, an ignition switch 74, and a wire 75 with the contact 68. The contact 69 in turn is connected by a wire 76 with a selector switch 77. An indicator light 78 has one side connected by a wire 79 to the switch 77 and its other side grounded. From the switch 77 a wire 80 extends to a rheostat 81 and a wire 82 extends from the rheostat to one side of the motor M. The other side of the motor is grounded by a wire 83.

The ignition switch 74 is the one used for the ignition system of the engine on which my fuel system is installed. An ignition wire 84 extends from the switch to the ignition system. I connect the ignition switch 74 in the circuit of my fuel system in the manner just described so that there can be no undesired operation of the fuel system during a time when the engine is not running. The ignition switch, being turned off, thereby renders the fuel system inoperative at any time its operation is unnecessary.

The pressure switch PS also controls a relay circuit and a clutch circuit as follows: A wire 85 connects the switch 77 with one side of a relay coil 86, the other side of which is grounded by a wire 87. A wire 88 extends from the selector switch 77 to a clutch switch CS having a movable contact 89 and a stationary contact 90. The stationary contact 90 is connected with one side of the clutch solenoid 56 by a wire 91.

The clutch solenoid 56 is also controlled by current through a wire 92 connecting the first mentioned side of the solenoid coil 56 with a clutch initiating switch of a relay indicated generally at R. The clutch initiating switch includes a movable contact 93 and a stationary contact 94. The contact 94 is connected by a wire 95 with a three-fingered commutator brush 96. The commutator brush 96 is associated with a commutator 97 having three segments 97a, 97b and 97c corresponding to the tanks 1, 2 and 3, respectively.

Individual commutator brushes 96a, 96b and 96c also coact with the commutator 97. The brushes 96a, 96b and 96c as well as the commutator 97 are turned a quarter turn in Figure 2 from the showing in Figure 3 to simplify the diagrammatic showing of circuits.

The commutator brushes 96a, 96b and 96c are connected by wires 98, 99 and 100, respectively, with stationary contacts 101, one of which is provided for each tank 1, 2 and 3. Movable contacts 102 are adapted to be engaged therewith by insulation projections 103 mounted on rheostat arms 104 of the tanks. The rheostat arms 104 are controlled by floats 105 (one for each tank 1, 2 and 3) so that different levels of fuel within the tanks cause the rheostat arms 104 to assume different positions.

The rheostat arms 104 coact with rheostat resistances 106, thereby changing the resistance values in them for the purpose of operating remotely reading electric fuel gauges 107, 108 and 109 for the respective tanks 1, 2 and 3. The electric resistance operated type of fuel level gauges illustrated are conventional and it is therefore believed unnecessary to further describe them. I find it convenient to utilize the conventional float operated rheostat arms 104 for the purpose of closing the switches 101 in response to low fuel level in my installation wherein the switches 101 perform an important function as will hereinafter appear.

The fuel level gauges 107, 108 and 109 may be mounted on a control panel 110 conveniently located for the pilot. The gauges may be labeled as "No. 1, No. 2," and "No. 3." A second extension shaft 111 is provided in connection with the shafts 36 and 37 and extends through the panel 110. A manual control lever 112 is mounted thereon and is provided with a pointer 113 which serves to indicate, by pointing to the proper gauge, which tank the selector valve is adjusted to. "Off" position is also indicated on the panel 110 for the pointer 113 when the selector valve is in a position not connected with any of the fuel supply tanks.

The movable contacts 102 of the fuel tanks 1, 2 and 3 are connected by wires 114, 115, 116 and 117 to the battery 72. A selector switch 118 is interposed between the wires 116 and 117 and operative with the switch 77 to open circuit position when it is desirable to render the automatic selector valve mechanism inoperative.

The clutch switch CS consists of a rigid arm 119 pivoted at 120 and normally biased toward a clutch switch cam 121 by a spring 122. The cam 121 has cam lobes 121a, 121b, 121c, corresponding to the tanks 1, 2 and 3, respectively. These lobes are adapted to coact with a lobe 123 on the arm 119. A spring arm 124 has one end connected with the arm 119 and carries the movable contact 89 on its other end. A lobe 125 is mounted on the spring arm 124.

For cooperation with the lobe 125, I provide a series of lobes 126a on a tripping cam 126. The cam 126 is loosely journalled on the sleeve 44 and a spirally coiled spring 127 is interposed as a driving connection between the bevel gear 46 and the tripping cam 126. The spring 127 has one end connected as by a pin 128 to the bevel gear and its other end connected as by a pin 129 to the tripping cam.

Practical Operation

Normally the various parts of my system assume the position shown in Figures 1 and 2 when all of the fuel tanks are full, except that the float 105 in the tank 1 would be in a raised position. The motor M has previously rotated the bevel gear 46 to an extent causing the spring

127 to be partially wound up. The unwound position of this spring is shown in Figure 4.

Due to the selector valve 4 being in the position of Figures 1 and 2, operation of the pump 20 will pump fuel from the tank 1 and through the switch pressure regulator 23 and the air-vapor eliminator 27 to the fuel injector 32. When the fuel pump runs out of fuel, there are three possible types of operation that can occur. I will refer to these operations as first, second and third types of operation.

First type of operation

Let us assume that the tank 1 is empty as a result of the fuel level therein having been gradually lowered by consumption of fuel or otherwise to the level shown in Figure 1. The float 105 in the tank 1 will accordingly be lowered to such a position that the rheostat arm 104 will cause the movable contact 102 to engage the stationary contact 101 of the tank 1 (see Figure 2). The fuel gauge 107 will have receded from full position to the position of Figure 1, indicating that tank 1 is empty.

A relay switch circuit can now be traced from the battery 72 through elements 117, 118, 116, the upper wire 115 leading to the fuel gauge 107, the wire 114 from the fuel gauge 107 to the switch contact 102 of the tank 1, and from the contact 101 of said tank through 98, 96*a*, 97*a*, 96 and 95 to the stationary contact 94 of the relay switch R. The relay switch, however, is open, so that there is no current flow. The fuel pump 20 continues to operate for withdrawing substantially all of the fuel from the tank 1.

The tank 1, upon being emptied, causes the fuel pump 20 to run out of fuel and therefore it can no longer maintain fuel pressure in the switch pressure regulator 23 and the conduit 61 leading to the bellows chamber 57 of the fuel pressure switch PS. Therefore the spring 59 expands the bellows 58 and moves the switch carriage 62—62*a*—63 inwardly or to the left, as in Figure 4, thus closing the switch PS by engagement of the switch arm 65 with the stud 70.

Closure of the switch PS effects energization of the selector switch 77 from the battery 72 through the elements 73, 74, 75, 68, 67, 69 and 76, and also energization of the indicator light 78 through the wire 79. Current from the switch PS to the selector switch 77 energizes three separate circuits in addition to the circuit for the indicator light 78. The first circuit is a motor circuit through elements 80, 81, 82 and 83. The second circuit is a relay coil circuit through elements 85, 86 and 87. The third circuit is a clutch switch circuit through elements 88, 124, 89, 90 and 91.

Energization of the first or motor circuit causes the motor M to start operating. Thus the motor M operates any time that the pressure switch PS responds to fuel pressure failure. The second or relay coil circuit causes the relay switch contact 93 to close against the electrically charged contact 94, thereby completing the relay switch circuit for the clutch solenoid 56 from the contact 93 through the wire 92. Thus actuation of the motor M and energization of the coil 56 takes place simultaneously, to avoid loss of time in rotating the selector valve from one position to another.

The closing of the switch PS energizes the relay coil 86, thereby closing the relay switch circuit by means of the contacts 93 and 94, as in Figure 4, to permit, at such time when the tank 1 or any of the other tanks with which the selector valve is connected at that particular time, energization of the clutch solenoid 56 for effecting clutching engagement between the clutch teeth 50 and 51. These teeth are shown engaged in Figure 4 and effect rotation of the selector valve from the position of Figure 1 to a position of full registration of the selector valve port 13 with the conduit 6 (see Figure 6). The dotted position in Figure 6 corresponds to the position of the cams 71 and 121 and of the commutator drum 97 shown in Figure 4. It will be noted that the selector valve has not quite completed a cycle of operation but only a segment of such cycle indicated at *a*.

Soon after the cam 121 starts rotating from the position of Figure 1, its cam lobe 121*a* will drop the lobe 123 of the clutch switch CS, thereby establishing the above referred to third or clutch switch circuit and also permitting the spring 127 to unwind as a result of the lobe 125 moving out of the path of movement of the lobes 126*a*. The spring will then remain unwound until the port 13 is registered with the conduit 6 (segment *a* plus segment *b* in Figure 6), after which there will be a time period of delay while the pressure in the fuel system is being built up to a point where it returns the switch carriage 62—62*a*—63 from the position of Figure 4 to the position of Figure 1. Such return of the carriage causes the lobe 65*a* of the switch arm to engage the cam lobe 71*b* (which would then be in the position of Figure 5). This effects opening of the circuit through the pressure responsive switch PS.

During the time period of delay mentioned in the preceding paragraph, the spring 127 will be wound from the position of Figure 4 to the position of Figure 2 and, when the pressure switch PS opens, the motor M will no longer be energized, thus leaving the spring in the wound-up condition of Figure 2 for a subsequent cycle of operation of the selector valve.

The third circuit above referred to may be traced through elements 88, 124, 89, 90 and 91, and maintains the clutch solenoid 56 energized through the wire 91 after it has been de-energized through the wire 92 as soon as the segment 97*a* of Figure 2 leaves the brush 96*a*.

If the tank 2 with which the selector valve is now in communication contains fuel, de-energization of the solenoid 56 will occur as a result of the circuit of the clutch being opened by the contact 89 separating from the contact 90 at valve registration position. The motor M will continue to rotate until the pressure in the switch PS is re-established by fuel supplied from the tank 2 which effects breaking of the motor circuit through movement of the switch arm 65 as already described. Such continued rotation winds the spring 127 to the position of Figure 2.

Second type of operation

Let us now assume a condition wherein the tank 2 contains fuel but for some reason or other, such as a leak in the line between the tank 2 and the selector valve, the pressure in the pressure switch PS as a consequence will not build up to the desired valve for feeding fuel to the engine. This condition is illustrated in Figure 5, wherein it will be noted that the contacts 101 and 102 of the tank 2 are open as a result of fuel in the tank. Under these circumstances the switch arm 65 will remain in closed position, as shown in Figure 5, thereby maintaining the cir-

cuit of the motor M energized. The motor will continue to run but the clutch solenoid **56** will be de-energized, since the contacts **101** and **102** in the tank **2** are out of engagement and the relay switch circuit is thus broken across **101** and **102**, even though **97***b* is bridging **96** and **96***b*.

The continued rotation of the motor now comes into play to bring about a re-energization of the clutch solenoid **56** through a different circuit than normal as described in connection with Figures 1 and 4. Such re-energization of the clutch solenoid occurs after a time interval which is greater than the first mentioned time interval required for normally building up the fuel pressure in the pressure responsive switch chamber **57** after the selector valve is moved to registry with a filled tank. This second time interval of delay for operating the clutch solenoid **56** by closing the contacts **89** and **90** through parts **125** to **129**, **46** and **47**, is as follows: As long as the motor M is running and the clutch solenoid **56** is de-energized, the selector valve will remain stationary in the established communicative position with the lobe **121***a* engaging the lobe **123** of the contact carrying arm **124** and thereby separating the contacts **89** and **90** at the time full registration of the port **13** and conduit **6** is accomplished, and positioning the lobe **125** in the path of a lobe **126***a* of the cam **126**. The cam **126** in turn is driven by the motor M through the spring **127**, as represented in Figure 2 wherein the spring is partially wound. Since rotation of the tripping cam **126** is prevented, the spring **127** will, however, become further wound or tensioned as in Figure 5 until the tension is increased to such an extent as to cause a flexure of the spring contacting arm **124** to thereby effect engagement of the contacts **89** and **90**. This will effect re-energization of the solenoid **56** to bring the clutch teeth **50** and **51** into engagement for rotating the valve to the next succeeding position.

The lobe **121***b* will soon disengage the lobe **123** so as to release the lobes **126***a* to permit unwinding of the spring **127** and the spring **122** will then retain the contacts **89** and **90** in engagement, as in Figure 4, so that rotation of the selector valve will not be stopped as a result of the contacts **101** and **102** of the tank **2** being separated. Accordingly, the selector valve will rotate until such time as the cam lobe **121***c* reopens the clutch switch CS to the position of Figure 2. Again, if the pressure in the pressure switch is built up to the desired value within the time interval allowed for this purpose by partial winding of the spring **127** as in Figure 2 after registration of the port **13** occurs with relation to the conduit **7** and consequent opening of the clutch switch circuit at **89**–**90**, the switch arm **65** will be moved to a position to break both the relay coil circuit and the motor circuit.

Third type of operation

Whether the selector valve has passed through the first type of operation or through the second type of operation, there is a third type of operation it will pass through in the event that the port **13** is registered with an inlet conduit from which no fuel is obtained as a result of the tank corresponding thereto being empty and its switch **101**—**102** being thereby closed. Assuming, for instance, that the tank **2** is empty when the selector valve reaches the position of Figure 4, then instead of the clutch solenoid **56** being de-energized as a result of separation of contacts **89** and **90** (after slight further rotation of the selector valve), the relay switch circuit and thereby the circuit for the solenoid **56** will remain energized through the brush **97***b* bridging the brushes **96** and **96***b*. Accordingly the selector valve will proceed without hesitation, and thereby in a minimum of time, to its next position so as to receive fuel from the tank **3**. This operation eliminates any time delay between shifting of the selector valve from tank **1** to tank **2** and from tank **2** to tank **3** when the tank **2** is empty, which of course is a desirable feature, as it is desirable to connect the fuel system with a tank having fuel in the shortest possible time.

From the foregoing it is obvious that the clutch switch CS is the controlling factor for stopping the rotation of the selector valve when there is fuel in the tank with which the selector valve comes into communication. On the other hand, the switch **101**—**102** of the new fuel source is the controlling factor for stopping rotation of the selector valve when there is a failure of fuel as by a leak in the conduit from any of the tanks to the selector valve. Under normal operating conditions, when the fuel tanks are properly filled there is a time delay period interposed for permitting build-up of fuel pressure in the pressure responsive switch to de-energize the selector valve motor and thereby eliminate possibility of further operation of the selector valve until such time as the new fuel source fails. Any time connection is made with a tank that does not contain fuel, however, the time delay period is eliminated and the selector valve operates at its normal high speed on to a second or third position beyond its previous position, all depending of course on the presence or absence of fuel in the tanks with which the selector valve is successively connected.

By way of example, it may take about 1½ seconds for the selector valve to move from one position to its next position, and then a 3-seconds delay may be interposed while the spring **127** is moving from the position of Figure 4 to the position of Figure 2, such period being determined by the time it takes for the fuel pressure to build up to a point where it moves the pressure switch from the Figure 4 position to the Figure 2 position. Thereupon, the entire mechanism is conditioned for a subsequent cycle of operation. On the other hand, however, if there is no build-up of pressure to open the pressure switch, then the spring **127** is wound further until it assumes the position shown in Figure 5 and effects another cycle of operation of the selector valve because the previous position did not produce the required fuel. If there is no fuel from the new source, as a result of the tank being empty, then the time delay period is eliminated and the selector valve rotates without hesitation on to the next position. The tank switches **101**—**102** accordingly serve as a means to insure that the selector valve will proceed to a tank containing fuel instead of futilely stopping at one that has been emptied by a bullet-hole leak, neglect of the attendant in filling it, or from any other cause.

The manual control handle **112** may be rotated at any time desired, regardless of the operation of the automatic selector valve drive mechanism. Such rotation is freely possible when the clutch solenoid **56** is de-energized, whereas when it is energized the clutch teeth **50** and **51** may be ratcheted past each other upon sufficient turning movement being imparted to the handle to

overcome the force of the solenoid tending to keep the clutch teeth engaged.

My system automatically uses substantially all of the fuel in any fuel tank before the selector valve is moved to a new position. This is a substantial improvement over prior systems dependent upon manual selector valve operation in response to float operated indicating lights. In the first place, such floats necessarily turn the lights on before all the fuel is exhausted, and in the second place the pilot might not be closely watching the lights and therefore would neglect to "switch over" until the engine begins to falter. When it is desired to render my automatic selector mechanism inoperative independent of the ignition switch **74**, the selector switch **77** may be opened.

Some changes may be made in the construction and arrangement of the parts of my fuel system without departing in any way from the real spirit and purpose of my invention. It is therefore my intention to cover by my appended claims any modified forms of structure or use of mechanical equivalents as may be reasonably included within their scope without sacrificing any of the advantages thereof.

What I claim as my invention, and on which I desire to secure Letters Patent of the United States, is:

1. For use in a fuel system having a series of fuel tanks and a selector valve for selectively connecting the fuel tanks to a source of fuel consumption; a selector valve drive comprising a shaft, a driven gear on said shaft, a driving gear meshing therewith, a motor for rotating said driving gear, a clutch for operatively connecting said motor with said driving gear, a multi-circuit commutator driven synchronously with said selector valve shaft, a relay switch in series therewith, a fuel pressure responsive switch for energizing said motor and closing said relay upon failure of fuel pressure supplied to said source of fuel consumption, a tank switch for each of the series of fuel tanks and electrically connected, one in each circuit of each commutator, a tripping cam driven by said motor through a yielding connection, a clutch switch cam operated synchronously with said selector valve shaft, a clutch switch so constructed and arranged between said tripping cam and said clutch switch cam as to be closed by the clutch switch cam upon rotation thereof in response to an empty tank condition and of fuel pressure to said source of fuel consumption resulting therefrom until such time as the advancing cam lobe of the clutch switch cam causes an open circuit condition through said clutch switch whereupon said clutch switch moves into the path of the next advancing cam lobe of said tripping cam, joint clutch switch and tripping cam engagement continuing until predetermined driving tension build-up in said yielding connection causes said tripping cam to reestablish a second circuit condition of said clutch switch, resulting thereby in engagement of said clutch to cause rotation of said selector valve shaft to another position of port registration when fuel pressure fails to be built up in said pressure responsive switch due to continued failure of fuel for said source of fuel consumption and, due to presence of fuel in a tank with which the selector valve is then connected, the circuit through said commutator is opened.

2. For use in a fuel system including a plurality of fuel tanks and a selector valve for connecting various of the fuel tanks one at a time to a source of fuel consumption; a selector valve drive comprising a driven gear operatively associated with the selector valve, a driving gear meshing therewith, a motor for rotating said driving gear, a clutch for operatively connecting said motor with said driving gear, a multi-circuit commutator driven synchronously with the selector valve, a relay switch in series therewith, a fuel pressure responsive switch for energizing said motor and closing said relay upon failure of fuel pressure supplied to said source of fuel consumption, a tank switch for each of the plurality of fuel tanks and electrically connected, one in each circuit of said commutator, a tripping cam, a yielding connection between said motor and said tripping cam, a clutch switch cam, a clutch switch between said tripping cam and said clutch switch cam and closed by the clutch switch cam upon rotation thereof in response to an empty tank and failure of fuel pressure to said source of fuel consumption thereafter, clutch switch closure obtaining until such time as the advancing cam lobe of the clutch switch cam opens the circuit through said clutch switch whereupon said clutch switch moves into the path of the next advancing cam lobe of said tripping cam, joint clutch switch and tripping cam engagement continuing until build-up of fuel pressure in said pressure responsive switch opens the pressure responsive switch and thereby de-energizes said motor.

3. For use in a fuel system having a series of fuel tanks and a selector valve for selectively connecting the fuel tanks to a source of fuel consumption; a selector valve drive comprising a motor, a clutch for operatively connecting said motor with the selector valve, a multi-circuit commutator and a clutch switch cam driven synchronously with the selector valve, a fuel pressure responsive switch effective upon failure of fuel pressure supplied to said source of fuel consumption to energize said motor and to energize said clutch, a tank switch for each of the series of fuel tanks and electrically connected, one in each circuit of said commutator, a tripping cam driven by said motor through a yielding connection, a clutch switch so constructed and arranged between said tripping cam and said clutch switch cam as to be closed by the clutch switch cam upon rotation thereof until such time as the next advancing cam lobe of said clutch switch cam opens the circuit through said clutch switch, said clutch switch thereupon assuming a position in the path of the next advancing cam lobe of said tripping cam, said tripping cam being held against rotation by said clutch switch until predetermined driving tension has been built up in said yielding connection to cause said tripping cam to close said clutch switch thereby rendering said clutch operative to cause rotation of the selector valve to a further selector valve position.

4. For use in an automatic fuel system including a plurality of fuel tanks and a selector valve hydraulically connected between the plurality of fuel tanks and a fuel pump operative to pump fuel to an engine or the like; a motor and an electrically controlled clutch for operating the selector valve at relatively high speed when changing from one selector valve position to the next, a fuel pressure responsive switch responding to the pressure of the fuel being pumped and controlling said motor and clutch, said selector valve, in a predetermined position, effecting opening of said fuel pressure switch, means for

stopping the selector valve when it has progressed to a position of alignment of its ports, a relay, a switch for each fuel tank operable to closed circuit position when the tank is empty, a commutator operatively connected to the selector valve and electrically connected in the circuit of said tank switches to effect establishment of a circuit to said switch of said relay upon an empty tank condition occurring, said fuel pressure responsive switch energizing said relay to cause the switch thereof to energize said clutch, and means for opening the circuit through said clutch and maintaining said circuit open for a time period of delay after the selector valve assumes a port registration position and prior to de-energization of said motor by opening of said pressure responsive switch in response to failure of pressure of the fuel being pumped to the engine.

5. For use in an automatic fuel system including a plurality of fuel tanks and a selector valve for hydraulically connecting the plurality of fuel tanks one at a time with a fuel consuming device: a motor and a clutch for operating the selector valve from one selector valve position to the next, a fuel pressure and selector valve position responsive device for controlling said motor, the fuel pressure responsive portion thereof responding to the pressure of the fuel supplied to the fuel consuming device, means for stopping the selector valve when it has reached port alignment position, a float actuated control device for each fuel tank operable to control position when the tank is empty, said fuel pressure responsive device cooperating therewith for rendering said clutch operable, and means for rendering said clutch temporarily inoperable and maintaining it so for a time period of delay after the selector valve assumes a port registration position.

6. For use in an automatic fuel system including a plurality of fuel tanks and a selector valve hydraulically connected between the plurality of fuel tanks and a fuel pump operative to pump fuel to an engine or the like; a motor, a clutch for operating the selector valve by said motor from one selector valve position to the next, a fuel pressure responsive control device for operating said motor upon failure of fuel from said pump, said device responding to the pressure of the fuel supplied to the fuel consuming device, the selector valve in a predetermined position effecting operation of said fuel pressure responsive control device to its inoperative position upon fuel pressure being re-established, means for stopping the selector valve when it has progressed to a position of alignment of its ports, a fuel level responsive control device for each fuel tank operable when the tank is substantially empty to cooperate with said fuel pressure responsive control device to cause it to render said clutch operable, and means for rendering said clutch inoperable and maintaining it in inoperable position for a time period of delay after the selector valve assumes port registration position and providing fuel pressure is re-established.

7. For use in an automatic fuel system having a series of fuel tanks and a selector valve for successively connecting the fuel tanks with a fuel pump or the like; a shaft for the selector valve, a motor for rotating said shaft to change the selector valve from one position to the next one, a clutch connection between said motor and said selector valve shaft, a fuel pressure responsive switch for controlling said motor and said clutch and thereby the rotation of said shaft in response to the pressure of the fuel being supplied by said fuel pump, a cam on said shaft cooperating with said fuel pressure switch to open the switch when the shaft assumes a position of alignment of the ports of the selector valve in conjunction with fuel pressure being built up in said fuel pressure switch, means for delaying the operation of the selector valve after it has reached port alignment position, a switch for each fuel tank operable when the tank is empty and the pressure of fuel thereby fails to build up in said pressure responsive switch to render said fuel pressure switch ineffective to open the circuit of said motor and to eliminate delaying the further operation of the selector valve, and a commutator on said shaft having segments corresponding to the fuel tanks and electrically connected in the circuits of said tank switches.

8. For use with an automatic fuel system having a plurality of fuel tanks and a selector valve for selectively connecting any one of the plurality of fuel tanks with a fuel pump or the like; a shaft for the selector valve, a motor for rotating said shaft, a clutch connection between said motor and said shaft, a fuel pressure responsive switch responding to the pressure of the fuel being supplied by said fuel pump and controlling said motor and said clutch, a cam on said shaft cooperating with said fuel pressure switch to open the switch when the shaft assumes a position of alignment of the ports of the selector valve dependent upon fuel pressure build-up in said fuel pressure switch, and means for delaying the operation of the selector valve with respect to said motor after port alignment position has been reached and until fuel pressure build-up in said pressure responsive switch occurs.

9. For use with an automatic fuel system having a plurality of fuel tanks and a selector valve for selectively connecting any one of the plurality of fuel tanks with a fuel pump or the like: a motor for rotating the selector valve, a clutch connection between said motor and the selector valve, a fuel pressure responsive switch responding to the pressure of the fuel being supplied by said fuel pump and controlling said motor and said clutch, said pressure responsive switch being opened upon the selector valve assuming a position of alignment of its ports and upon fuel pressure being built up in said fuel pressure responsive switch, and means for delaying the operation of the selector valve in a position of port alignment for a time period sufficiently long to permit such fuel pressure build-up providing the new fuel tank with which the selector valve then communicates has fuel to supply the pump.

10. For use with a fuel system having a plurality of fuel tanks and a selector valve connected between the plurality of fuel tanks and a fuel pump operative to pump fuel to a fuel consuming device; a motor for operating the selector valve at relatively high speed when changing from one selector valve position to the next, a fuel pressure responsive switch responding to the pressure of the fuel being supplied by said fuel pump and controlling said motor, an electrically operated clutch between said motor and the selector valve and controlled by said fuel pressure responsive switch, means for stopping the operation of the selector valve after progression thereof to a position of port align-

ment, said means including a clutch switch, a tripping cam spring driven by said motor for closing said clutch switch after predetermined build-up of spring tension in the spring of said tripping cam after said clutch switch has been opened by the selector valve at said position of port alignment, a fuel level responsive switch for each fuel tank and operative when the tank is empty to render said clutch ineffective to stop the selector valve relative to said motor, and a commutator operatively connected with said selector valve and electrically connected in the circuits of said tank switches.

11. For use with an automatic fuel system having a plurality of fuel tanks and a selector valve hydraulically connected between the plurality of fuel tanks and a fuel consuming device; a motor for operating the selector valve through successive selector valve positions, a fuel pressure responsive switch responding to the pressure of the fuel being supplied to said fuel consuming device and controlling said motor, an electrically operated clutch between said motor and the selector valve, means for disengaging said clutch after progression of the selector valve to a port alignment position, said means including a clutch switch, a spring driven tripping cam for closing said clutch switch after predetermined build-up of spring tension after said clutch switch has been opened by the selector valve at said port alignment position, a tank switch for each fuel tank and operative when the tank is substantially empty to render said fuel pressure responsive switch ineffective to stop said motor and ineffective to de-energize said clutch, and a commutator operatively connected with the selector valve and electrically connected in the circuits of said tank switches.

12. For use with a fuel system including a plurality of fuel tanks and a selector valve for connecting any one of the plurality of fuel tanks with a fuel pump; a motor for operating the selector valve through successive selector valve positions, a fuel pressure responsive switch responding to the pressure of the fuel being supplied by said fuel pump and controlling said motor, an electrically operated clutch between said motor and the selector valve and controlled by said fuel pressure responsive switch, a clutch switch for also controlling said clutch, means for stopping the operation of the selector valve upon progression thereof to a position of port alignment, a switch for each fuel tank, a commutator connected for operation by the selector valve and electrically connected in the circuit of each of said tank switches, and a relay switch connected in the circuit of said commutator, said relay switch being operative to control said clutch in conjunction with said clutch switch and the relay coil thereof being under control of said fuel pressure responsive switch.

13. For use with a fuel system including fuel tanks and a selector valve for successively connecting the fuel tanks with a fuel pump; a motor for operating the selector valve at relatively high speed when changing from one selector valve position to the next, said valve being also manually operable, a fuel pressure responsive control device for controlling said motor in response to the pressure of the fuel supplied by said pump, a clutch connection between said motor and the selector valve and controlled by said fuel pressure responsive control device, a second clutch control device for stopping the operation of the selector valve upon progression thereof to a position of port alignment, a control device for each of said fuel tanks and responsive to fuel level therein, said second clutch control device being operated by said fuel pressure responsive device and said fuel tank control devices in conjunction with each other to render said clutch inoperative for a time period of delay after the selector valve reaches its port alignment position.

14. For use in an automatic fuel system having a plurality of fuel tanks and a selector valve connected between the plurality of fuel tanks and a fuel pump operative to pump fuel to a fuel consuming device; a motor for operating the selector valve when changing from one selector valve position to the next, a fuel pressure and selector valve position responsive switch for controlling said motor in response to the pressure of the fuel supplied by said pump, an electrically operated clutch for operatively connecting said motor with the selector valve, said clutch being under control of said fuel pressure responsive switch, and means synchronized with the operation of the selector valve for interposing a temporary time delay period in the operation of the selector valve after it has progressed to a position of alignment of its ports.

15. For use in a fuel system including a plurality of fuel tanks and a selector valve for successively connecting the plurality of fuel tanks with a fuel pump; a motor for operating the selector valve from one selector valve position to the next, a fuel pressure responsive switch for controlling said motor in response to the pressure of the fuel supplied by said pump, said fuel pressure responsive switch being closed by a drop of fuel pressure and carried in closed position to another position upon subsequent build-up of fuel pressure, a cam operated in synchronism with said selector valve for opening said switch when in said another position, and means for stopping the operation of the selector valve with respect to said motor when the selector valve has progressed through a cycle to a position of alignment of its ports, said means including a clutch switch, a clutch switch cam and a spring driven tripping cam for operating said clutch switch, said clutch switch being operated by said clutch switch cam and tripping cam to closed circuit position after the start of a selector valve operation, being opened by said clutch switch cam upon completion of a cycle of selector valve movement, said tripping cam being thereupon driven by said motor to effect build-up of spring tension in the spring thereof while fuel pressure is being built up in said fuel pressure switch and, if there is no such build-up of fuel pressure, effecting further build-up of spring tension sufficient to close said clutch switch and to thereby initiate another cycle of movement of the selector valve.

16. For use in a fuel system including a plurality of fuel tanks and a selector valve for connecting the plurality of fuel tanks in successive order with a fuel pump; a motor for operating the selector valve, a fuel pressure responsive switch for controlling said motor in response to the pressure of the fuel supplied by said pump, said fuel pressure responsive switch being closed by a drop of fuel pressure and carried in closed position to another position upon subsequent build-up of fuel pressure therein, a cam operated in synchronism with the selector valve for opening said switch when in said another position, and means for stopping the operation of the selector valve for a time period when the selector valve has progressed to a new position of port alignment, said means

including a clutch switch, a clutch switch cam and a spring driven tripping cam for operating said clutch switch to closed circuit position after the start of a selector valve operation and for opening said clutch switch at the completion of a selector valve movement, said tripping cam being thereupon operable to effect build-up of tension in said spring during a fuel pressure build-up time interval, and means controlled by said pressure responsive switch to shunt the circuit of said clutch switch to insure rotation of the selector valve to a further port alignment position upon failure of fuel pressure to be built up.

17. For use in an automatic fuel system having a plurality of fuel tanks and a selector valve connected between the plurality of fuel tanks and a fuel pump or the like; a motor for operating the selector valve, a fuel pressure responsive switch for controlling said motor in response to the pressure of the fuel supplied by said pump, an electrically operated clutch connection between said motor and the selector valve, said clutch connection being jointly under control of said fuel pressure responsive switch and the selector valve, and means responsive to selector valve position for stopping the rotation of the selector valve while permitting said motor to continue running for a time period after the selector valve reaches port alignment position.

18. For use in an automatic fuel system having a plurality of fuel tanks and a selector valve connected between the plurality of fuel tanks and a fuel pump operative to pump fuel to a fuel consuming device; a motor for operating the selector valve at high speed from one selector valve position to the next, a fuel pressure responsive control device for controlling said motor in response to the pressure of the fuel supplied by said pump, a clutch connection between said motor and the selector valve, said clutch connection being jointly under control of said fuel pressure responsive control device and selector valve position, and means responsive to selector valve position for temporarily stopping the rotation of the selector valve after it approaches port alignment position and for retaining the valve stopped at such position for a period of time sufficient to permit build-up of fuel pressure in said fuel pressure responsive switch by said fuel pump obtaining fuel from the now source, such build-up of pressure effecting operation of said fuel pressure responsive switch to stop said motor.

19. For use in an automatic fuel system including a plurality of fuel tanks and a selector valve for hydraulically connecting the plurality of fuel tanks with a fuel consuming device to which the fuel is fed under pressure; a motor for operating the selector valve, a fuel pressure responsive switch for controlling said motor in response to the pressure of the fuel supplied to said fuel consuming device, an electrically operated clutch connection between said motor and the selector valve, said fuel pressure responsive switch being opened by the selector valve at port registration position, a switch for each fuel tank, a commutator operatively connected with the selector valve and electrically connected in the circuits of said tank switches, a relay controlled by said fuel pressure responsive switch and having its relay switch in the circuit of said commutator, said relay switch being effective to also control said clutch, a clutch switch in circuit with said fuel pressure responsive switch to additionally control said clutch, said clutch switch being conjointly controlled by the selector valve and said motor to effect temporary stopping of said selector valve at a position of port alignment.

20. For use in an automatic fuel system including a plurality of fuel tanks and a selector valve for hydraulically connecting the plurality of fuel tanks with a fuel consuming device to which the fuel is fed under pressure; a selector valve driving system comprising a motor for driving the fuel selector valve, a switch responsive to the fuel pressure of the fuel supplied to the fuel consuming device, said switch energizing said motor upon fuel pressure failure, a clutch connection between said motor and the selector valve, means for rendering said clutch connection ineffective for a time period upon the selector valve assuming a position of port registration, said fuel pressure switch being movable in closed circuit position by build-up of fuel pressure therein during said time period to a predetermined position, the selector valve at port alignment position effecting movement of said switch from said predetermined position to open circuit position to stop said motor and disengage said clutch.

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