Dec. 20, 1949 C. D. KOECHLING 2,491,668

GROUND TRAINER FOR TRAINING AIRCRAFT CREW MEMBERS

Filed April 26, 1946 4 Sheets-Sheet 1

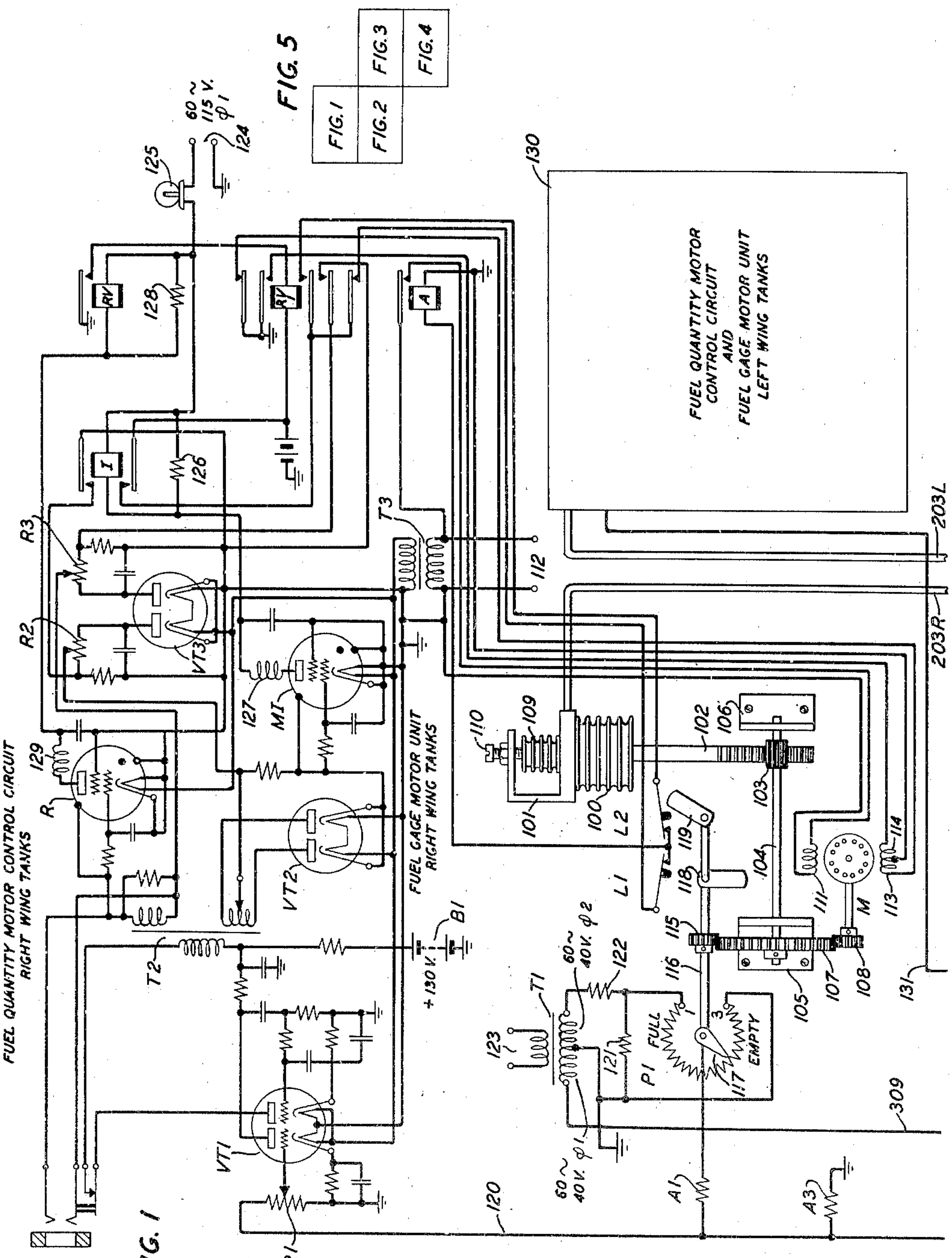

FIG. 1

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GROUND TRAINER FOR TRAINING AIRCRAFT CREW MEMBERS

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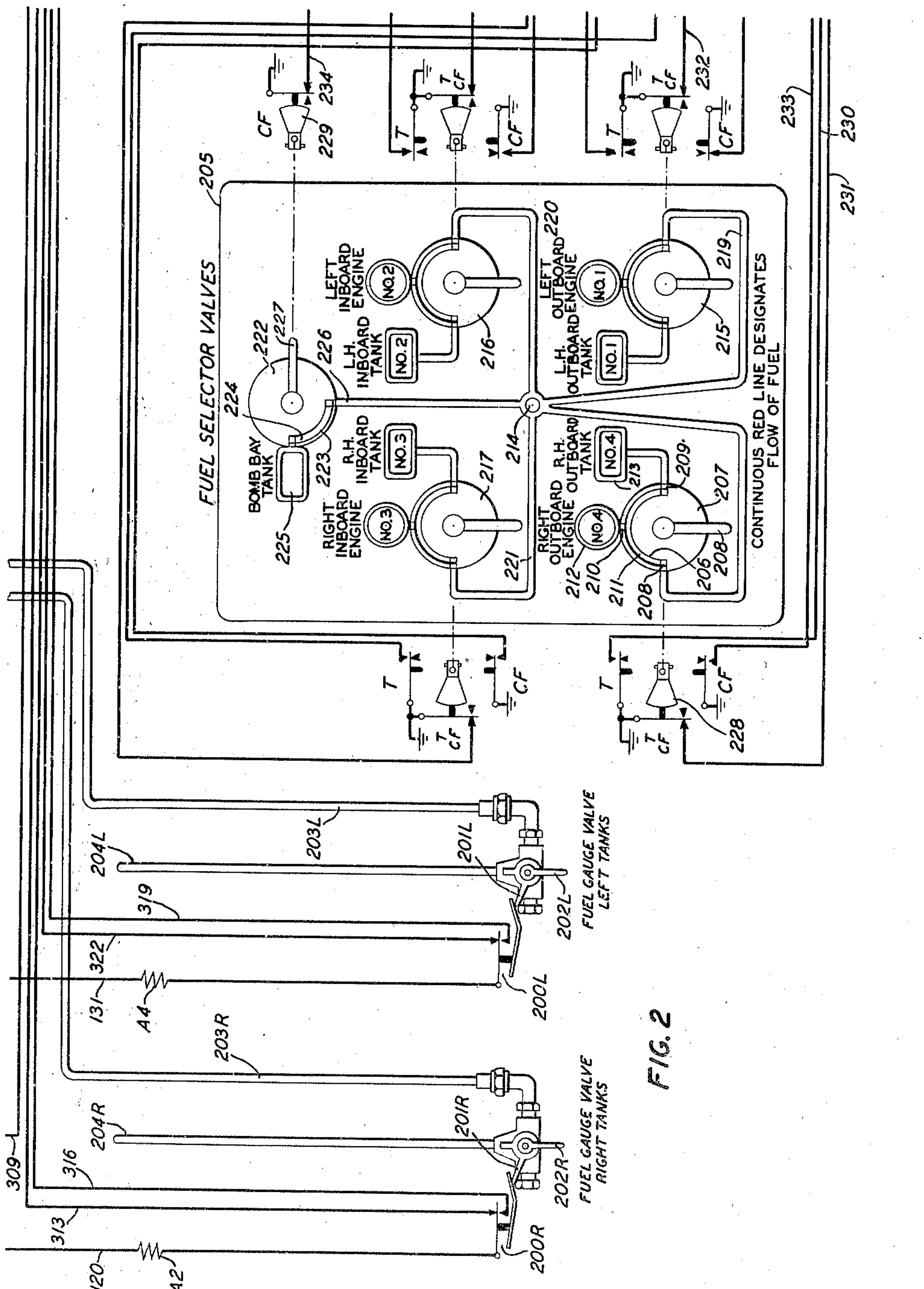

FIG. 2

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GROUND TRAINER FOR TRAINING AIRCRAFT CREW MEMBERS

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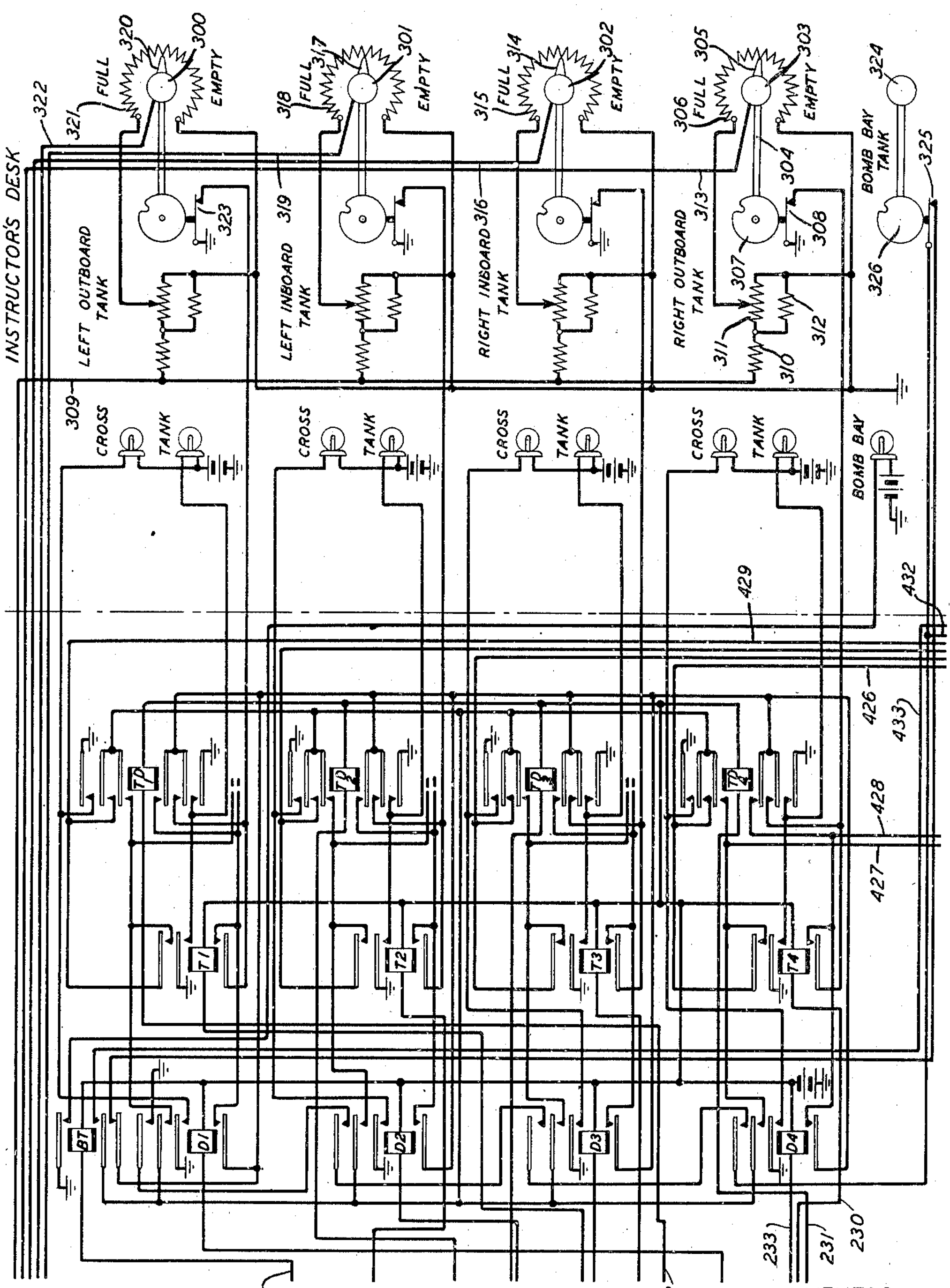

FIG. 3

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GROUND TRAINER FOR TRAINING AIRCRAFT CREW MEMBERS

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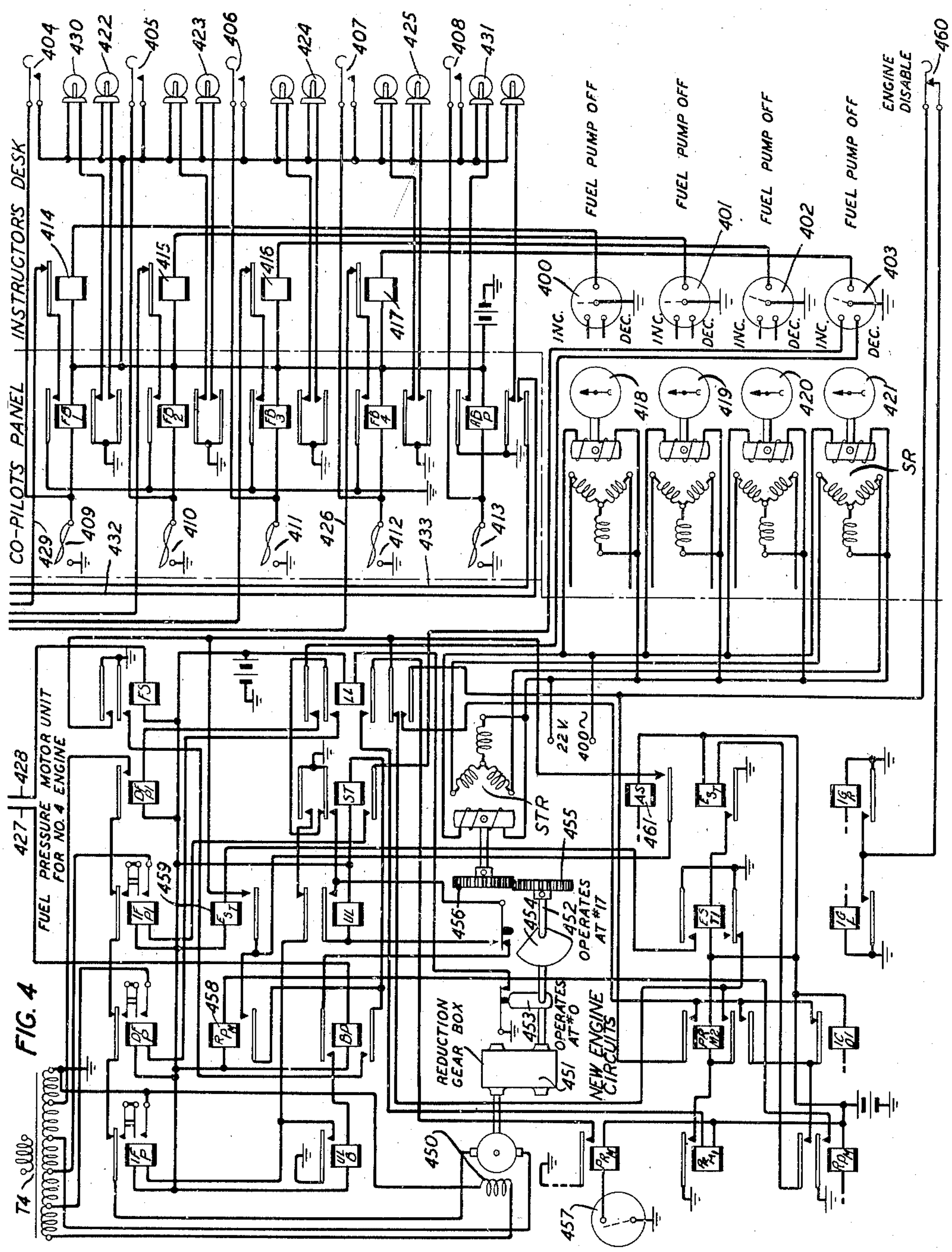

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Patented Dec. 20, 1949

2,491,668

UNITED STATES PATENT OFFICE

2,491,668

GROUND TRAINER FOR TRAINING AIRCRAFT CREW MEMBERS

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Application April 26, 1946, Serial No. 665,025

9 Claims. (Cl. 35—12)

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This invention relates to a ground trainer for training an aircraft crew and more particularly to circuits and apparatus for simulating the functioning of the fuel distribution system of a multiengined airplane.

In an airplane of the type which the trainer of the present invention is designed to simulate, that is, in an airplane having four engines, fuel may be pumped to the carburetors of the four engines from four fuel tanks located in the wings and a fuel tank located in the bomb bay. The distribution of the fuel is controlled by a group of selector valves located on a panel at one of the crew member's station or, in this particular case, at the navigator's station on the flight deck.

There are five tank selector valves on the panel individualized to the four wing tanks and to the bomb bay tank. Each one of four of these valves, allocated to the wing tanks, has three ports: one, the inlet port to the associated tank; the second, an outlet to the engine fuel supply line of the engine allocated to such valve and the third a connection with a cross feed line. Each of these valves is so designed that the inlet from the tank and the outlet to the engine may be opened simultaneously by turning the handle so that a red "flow" band on the panel is uncovered by an arcuate slot in the valve dial to connect the band on the panel marked "Tank No. ——" and the band on the panel marked "Engine No. ——." With the handle in this position the cross feed port is closed. The handle may be turned so that the inlet port from the tank, the outlet port to the engine and the cross feed port are all open at the same time. The "flow" band uncovered by the dial at this time connects the band on the panel marked "Tank No. ——," the band on the panel marked "Engine No. ——" and the cross feed band on the panel. Or the handle may be turned to close off the inlet port from the tank leaving the cross feed port and outlet to the engine open. In the latter case the "flow" band uncovered by the dial connects the band on the panel marked "Engine No. ——" and the cross feed band. In the fourth or "Off" position of the handle all ports are closed.

The fifth selector valve on the panel has an inlet port from the supply leading from the bomb bay tank and an outlet port to the cross feed line. Thus when the handle is in one position these ports are both open and the "flow" band uncovered by the valve dial connects the band on the panel marked "bomb bay tank" with the cross feed band on the panel. In the other position of the handle both ports are closed.

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Fuel is supplied to each engine carburetor through a pump driven by such engine, which pump incorporates therein a relief valve which permits fuel to be forced around the pump to the carburetor in case the pump fails. Four electrically driven booster pumps, one assigned to each wing tank, are provided to transfer fuel from one wing tank to another and to maintain pressure in the fuel line in the event of engine driven pump failure. They are used also to augment pressures during take-off, landing and at high altitudes and in priming operations for starting the engines. Another booster pump is provided to transfer fuel from the bomb bay tank to the wing tanks.

Two fuel sight gauges are provided in the navigator's station each provided with a three-port, two-way valve so that the tube of one of the gauges may be connected at will to either the outboard or inboard wing tank in one wing and the tube of the other gauge may be connected to either the outboard or inboard wing tank in the other wing. Fuel pressure gauges, one for each engine, are mounted on the cockpit instrument panel at the copilot's station.

Fuel is drawn from the four main tank outlets through the booster pumps by way of the main fuel lines to the selector valves and thence through the main lines to each engine driven fuel pump and thence to each carburetor. Thus the normal route for fuel flow is from each main wing tank to each corresponding engine (No. 1 tank to No. 1 engine, No. 2 tank to No. 2 engine, No. 3 tank to No. 3 engine and No. 4 tank to No. 4 engine).

The installation of the cross feed manifold, however, provides a means for diverting flow from the normal tank to engine route so that fuel from any wing tank may be directed to another engine or to another wing tank and the associated engine. By means of the cross feed system fuel from any tank can be cut off from its corresponding engine which can then be fed from any of the other tanks through the cross feed manifold. Flow of fuel from the bomb bay tank is through the bomb bay booster pump, up through the bomb bay feed line, through the selector valve on the valve panel to the cross feed manifold and thence to the wing tank to which fuel is to be selectively transferred.

It is the object of the present invention to provide means whereby the operations of a fuel system of the character hereinbefore described are simulated.

A further object of the invention is to provide electrically operated means for simulating the effect of the operation of fuel selector valves on the engines and fuel pressure indicators of an airplane.

A further object of the invention is to provide electrically operated means for simulating the operation of the fuel gauges of an airplane.

A still further object of the invention is to provide electrically operated means controlled at an instructor's desk for simulating the failures of engines and booster pumps and the exhaustion of fuel from any fuel tank.

These and other objects pertinent thereto are attained by the structure set forth in the appended claims and disclosed in the following detailed description when read in connection with the accompanying drawing in which:

Fig. 1 discloses in the lower portion thereof the fuel gauge motor unit for raising and lowering an indicating fluid in the tube of one gauge to simulate the indication of the quantity of fuel in either of the right wing tanks, in the upper portion thereof the motor control circuit for controlling such motor unit, and a box shown in the lower right portion thereof representing the motor unit and control circuit therefor for raising and lowering an indicating fluid in the tube of a second gauge to simulate the indication of the quantity of fuel in either of the left wing tanks;

Fig. 2 shows the two fuel quantity gauges and the fuel selector valve panel of an airplane modified to function in accordance with the present invention;

Fig. 3 shows in the left portion thereof relays and circuits controlled from the selector valves of Fig. 2, in the center portion thereof indicating lamps at an instructor's desk for indicating to the instructor the position to which the selector valves of Fig. 2 have been adjusted by a crew member and in the right portion thereof controls and potentiometers operable thereby for simulating the fuel quantity in each of the wing tanks;

Fig. 4 shows in the upper left portion thereof fuel pressure motor units and the control circuits therefor for simulating the creation of fuel pressure in the fuel feed line to one of the engine carburetors of an airplane, due to the operation of the engine driven pump and a booster pump, in the lower portion thereof such relays and circuits which simulate the operation of said one engine, in the dot-dash rectangle labeled "Co-pilot's panel," switches and relays controlled thereby for simulating the operation of the booster pumps which would be associated with the four wing tanks and in the right portion thereof lamps, control switches and fuel pressure indicators at the instructor's desk; and

Fig. 5 is a diagram showing how the other figures of the drawing should be assembled to fully disclose the invention.

The fuel gauges and associated valves disclosed in Fig. 2 are similar to those actually installed in an airplane except that the fuel line connections thereto are omitted, one of the inlets to each valve being closed by a plug and the other inlet being connected by a pipe to the Sylphon bellows of the associated gauge motor unit shown in Fig. 1. A switch 200 has been added to each valve which is operable to one or the other of its circuit closing positions by a cam 201 mounted on the valve shaft, dependent upon whether the valve handle 202 is moved to a position in which an actual airplane gauge would be connected to a right wing tank or is moved to a position in which the gauge would be connected to a left wing tank.

Each gauge glass 204 has an indicating fluid therein the height of which in the glass is controlled by pressure applied from a Sylphon bellows connected to the gauge valve by a pipe 203 extending to the Sylphon bellows 100 of the associated motor unit. One end of the bellows 100 is connected to a frame casting 101 to which the pipe 203 connects and the other, or movable end of the bellows, is attached to a rack 102. The rack 102 meshes with a rack pinion 103 mounted on the shaft 104. Shaft 104 is journaled in bearings 105 and 106 and also has mounted thereon a gear 107 driven by a pinion 108 mounted on the rotor shaft of the motor M.

For enabling the height of the indicating fluid to be adjusted in the gauge glass 204 to the correct level when either wing tank to which the gauge appertains is full, an auxiliary bellows 109 is connected to the frame casting 101 and is adjustable to vary the pressure in the pipe 203 by the adjustment of the screw 110.

The motor M is of the reversible shaded-pole type having its main stator winding 111 energizable from the source of alternating current 112 under the control of relay A of the associated motor control circuit and having its shaded-pole windings 113 and 114 selectively short-circuited under the control of relay RV1 of the motor control circuit.

Gear 107 also through the pinion 115 drives an auxiliary shaft 116 on which are mounted the slider 117 of the balancing potentiometer P1 and the operating cams 118 and 119 of the limit switches L1 and L2, respectively. The slider 117 of the potentiometer is connected through the summing resistor A1 to the signal input conductor 120 of the associated motor control circuit and the winding is bridged by the resistor 121. The No. 3 winding terminal is connected to the grounded mid-tap of the secondary winding of transformer T1 and the No. 1 winding terminal is connected through resistor 122 to the right terminal of the secondary winding of transformer T1. The primary winding of transformer T1 is energized from the alternating current source 123 and, since the mid-tap of the secondary winding is grounded, potentials 180 degrees out of phase will appear between the mid-tap and the outer terminals of the secondary winding and as a consequence the winding of poteniometer P1 is energized by a potential represented as of phase $\varphi 2$. The cams 118 and 119 are so positioned on the shaft 116 that the cam 118 opens the contacts of the limit switch L1 when the slider 117 approaches the No. 1 terminal of the potentiometer winding to release relay A to stop the motor M and the cam 119 opens the contacts of the limit switch L2 to stop the motor when the slider approaches the No. 3 terminal of the potentiometer winding.

The fuel quantity motor control circuit shown in the upper portion of Fig. 1 is of the general type disclosed in Patent No. 2,428,767 granted October 14, 1947, to Albert-Davis-Gumley-Holden, and, in general, comprises a first dual vacuum tube VT1 which serves as a two-stage resistance coupled amplifier to amplify the control signal applied to the control grid of its left unit from the slider of gain control rheostat R1 which is connected to input control conductor 120, and to apply the amplified signal potential to the primary winding of step-up input transformer T2. The amplified signal is impressed from the lower secondary winding of the transformer through the dual diode tube VT2, serving as a full-wave rectifier, upon the control grid of the thyratron tube MI and the signal is also impressed from the upper secondary winding of the transformer upon the control grid of the thyratron tube R. Grid biases are applied to the control grids of the thyratron tubes MI and R from the secondary winding of the filament supply transformer T3 through the dual diode tube VT3 and are adjusted by the grid bias adjusting rheostats R2 and R3.

Tube MI upon firing causes the operation of the motor impulsing relay I which in turn controls relay A to apply power to the main stator winding 111 of the motor M. Tube R, upon firing, causes the operation of the motor reversing relay RV which in turn controls relay RV1 to short-circuit one or the other of the shaded-pole windings 113 or 114 of the motor M to cause such motor to turn in one or the other direction dependent upon whether relay RV1 is operated or unoperated.

Cathode heater current is supplied to the filaments of all the tubes from the secondary winding of the filament supply transformer T3. Anode potential is supplied to the anodes of tube VT1 from the +130-volt battery B1, anode potential is supplied from the 60-cycle, 115-volt source of phase $\varphi1$ current 124 through the ballast lamp 125, through the winding of relay I in parallel with resistor 126, and through the choke coil 127 to the anode of tube MI, and from the latter source through lamp 125, through the winding of relay RV in parallel with resistor 128 and thence through choke coil 129 to the anode of tube R.

A similar motor unit and control circuit therefor for controlling the level of the indicating fluid in the gauge glass 204L to simulate the indication of the quantity of fuel in the left wing tanks is provided, but to simplify the drawing this apparatus has been represented by the rectangle 130 in Fig. 1.

To control the fuel quantity motor control circuits of Fig. 1 whereby the fuel quantity gauges may be operated in simulation of the measurement of the quantity of fuel in the wing tanks, four fuel quantity controls are provided at the instructor's desk. The control 300 is operable to simulate the quantity of fuel in the No. 1 or left outboard wing tank and the controls 301, 302 and 303 are operable to simulate the quantity of fuel in the left inboard or No. 2, the right inboard or No. 3 and the right outboard or No. 4 tanks, respectively.

The control 303 is connected, for example, to a shaft 304 on which is mounted the slider 305 of a potentiometer 306 and the operating cam 307 of an off-normal switch 308. Cam 307 is cut to hold the switch 308 closed in all positions of the slider 305 except when the slider is at the lower terminal of the potentiometer winding to represent an empty condition of the right outboard wing tank. The winding of potentiometer 306 is energized by potential of phase $\varphi1$ which is applied from the left secondary winding of transformer T1, Fig. 1, over conductor 309, through resistor 310, through the calibrating rheostat 311, the winding of which is bridged by resistor 312, and thence through the winding of potentiometer 306 to ground. Potential of phase $\varphi1$ derived at the slider 305 of the potentiometer is thus a measure of the simulated amount of fuel in the right outboard tank and is a maximum when the tank is assumed to be full and the slider is positioned at the upper terminal of the potentiometer winding.

If the navigator desires to determine the amount of fuel in the right outboard tank, he will operate the gauge valve handle 202R to the position shown in Fig. 2 whereupon potential will be applied from the slider 305, over conductor 313, over the upper contacts of switch 200R, through summing resistor A2 and over control conductor 120 to the input of the fuel quantity motor control circuit for the right wing tank. Or if he desires to determine the amount of fuel in the right inboard tank, he will operate the gauge valve handle 202R to the alternate position whereupon potential of phase $\varphi1$ will be applied from the slider 314 of potentiometer 315, over conductor 316, over the lower contacts of switch 200R and thence as traced to the input of the fuel quantity motor circuit for the right wing tanks. In a similar manner potential may be supplied from the slider 317 of potentiometer 318, over conductor 319, and from slider 320 of potentiometer 321, over conductor 322, and thence over a contact of switch 200L, dependent upon the position of the gauge glass valve handle 202L, and resistor A4 to control conductor 131 extending to the fuel quantity motor control circuit for the left wing tanks.

It will be assumed that the navigator has operated valve handle 202R to the position disclosed and that potential of phase $\varphi1$ is thus applied to the input of the fuel quantity motor control circuit for the right wing tanks representative of the quantity of fuel in the right outboard wing tank as determined by the setting of potentiometer 306. This potential is amplified by the tube VT1, is rectified by the tube VT2 and appears as a positive potential on the control grid of tube MI. Tube MI thereupon fires on positive half cycles of the anode potential applied to its anode and causes the operation of relay I connected into its cathode-anode path over a circuit which may be traced from ground over the cathode-anode path through tube MI, through choke coil 127, through the winding of relay I in parallel with the resistor 126, and thence through ballast lamp 125 to the phase $\varphi1$ source of potential 124. At the same time the amplified signal potential appears as a potential of phase $\varphi2$ on the control grid of tube R and therefore the control grid of tube R will be rendered more negative during each positive half cycle of the anode potential applied to the anode of tube R. Consequently tube R does not fire and relays RV and RV1 do not operate. Thus upon each energization of relay I a circuit for relay A is established from battery over the lower contacts of relay I, over the lower back contact of relay RV1, over the contacts of limit switch L1, and through the winding of relay A to ground. Relay A upon each energization now applies power from the source 112 to the main stator winding 111 of motor M, over the previously traced circuit. With relay RV1 unoperated, the shaded-pole winding 113 is connected into a short circuit extending from ground over the upper back contact of relay RV1 and through such winding to ground. The motor M is therefore caused to rotate in such a direction as to rotate the slider 117 of the balancing potentiometer P1 towards the No. 1 terminal of its winding.

As the slider moves an increasing potential of phase $\varphi2$ is applied therefrom through resistor A1 to the input control grid of tube VT1 which opposes the signal potential of phase $\varphi1$ applied to the input of the tube VT1 from the slider of potentiometer 306 and has a consequence the predominant potential of phase $\varphi 1$ is gradually reduced and the tube MI responds thereto to gradually reduce the power impulses transmitted to the motor M whereupon the motor slows down. When the slider 117 of the balancing potentiometer has thus been moved to a position in which the phase $\varphi 2$ applied therefrom balances the signal potential of phase $\varphi 1$ applied from the slider 305 of potentiometer 306 at the instructor's desk, the tube VT1 will receive no input potential and therefore the tube MI will cease to fire and the motor M will stop. The shaft 116 will now have been rotated to a position representative of the quantity of fuel in the right outboard tank and through the gear 107, the pinion 103 and rack 102 the Sylphon bellows 100 will have produced a pressure in the pipe 203R and in the gauge glass 204R to move the indicating fluid in the glass to a level indicative of the quantity of fuel in the right outboard tank.

If it be assumed that this tank is full, the slider of potentiometer P1 will have been moved to the No. 1 terminal of the potentiometer winding and the indicating fluid will have been raised to the upper or full indication mark on the gauge glass 204R. If now the instructor moves the slider 305 of potentiometer 306 toward the lower terminal of its winding representative of a diminution of fuel in the right outboard tank, the balancing potential of phase $\varphi 2$ being now greater than the signal potential of phase $\varphi 1$ the predominating potential of phase $\varphi 2$ now applied to the input grid of tube VT1 causes tube R to fire and to thereby operate relay RV and causes tube MI to operate relays I and A to transmit power impulses to the motor M. Relay RV1 being now operated due to the operation of relay RV, the circuit of relay A now extends over the inner lower front contact of relay RV1, and the shaded-pole winding 114 of the motor is connected into a short circuit from ground over the upper front contact of relay RV1 and through the winding of tube 114 to ground. The motor M now runs in a direction to move the slider 117 of potentiometer P1 toward the No. 3 terminal of its winding thereby reducing the balancing potential of phase $\varphi 2$ applied to the input circuit of tube VT1 until this potential balances the new value of the phase $\varphi 1$ signal potential whereupon the motor will stop. Through the operation of the motor the bellows 100 has now been readjusted to reduce the pressure in the gauge glass 204R thereby lowering the level of the indicating fluid in such glass to indicate the reduced quantity of fuel in the right outboard wing tank.

The fuel selector valve panel 205 of Fig. 2 is identical with that of an actual airplane which the trainer simulates. Each valve shaft has a valve handle and a valve dial secured thereto. The dial has an arcuate slot therein, such as the slot 206 in the dial 207, and three radially disposed red bands 208, 209 and 210. On the face of the panel and adjacent to the periphery of the dial is a red circle 212 depicting the No. 4 engine, a red rectangle 213 depicting the No. 4 tank and a red depicted cross feed manifold junction 214, each having a red band extending therefrom. The ends of such three bands extend radially toward the valve dial 207, are disposed 90 degrees apart, and are joined by an arcuate red band 211, portions of which are exposed through the slot 206 in the dial when the valve handle 208 is turned to its different selection positions. These red bands represent the paths of fuel flow when the selector valve is in different selection positions. For example, with the valve handle 208 in the position shown, the arcuate band 211 is exposed to join the bands extending from the circle 212, from the rectangle 213 and from the cross feed junction 214 thereby representing that in such position of the valve handle, the valve on an actual airplane would permit the flow of fuel from the cross feed line to the No. 4 engine and to the No. 4 tank.

Should the handle 208 be moved to the left, the arcuate band 211 would be exposed to show only the interconnection of the bands extending from the circle 212 and the rectangle 213, representative of fuel flow from the No. 4 tank to the No. 4 engine and the closure of the valve port to the cross feed line, or should the handle 208 be moved to the right, the arcuate band 211 would be so exposed as to show only the connection of the rectangle 213 with the cross feed junction 214, representative of the fuel flow from the cross feed to the No. 4 engine and the closure of the port to the No. 4 tank.

The other wing tank selector valves have their dials 215, 216 and 217 similarly provided with arcuate slots which when the dials are turned, uncover arcuate bands interconnecting engine and tank representations and other bands 219, 220 and 221 representing other branches of the cross feed manifold. The dial 222 of the bomb bay tank selector valve is similarly provided with an arcuate slot 223 which in the position shown uncovers an arcuate red band 224 extending from the depicted bomb bay tank 225 to the band 226 depicting another branch of the cross feed manifold thereby representative of the connection of the bomb bay tank with the cross feed manifold. When the valve handle 227 is moved to another position, the arcuate band 224 is covered indicative of the disconnection of the bomb bay tank from the cross feed manifold.

Each of the selector valve shafts, for the purposes of the present invention is provided with a cam, such as the cam 228, which is effective to cause the selective closure of one or more sets of contact springs. Associated with the cam on the shaft of each wing tank selector valve are three sets of contact springs such as T, T-CF and CF and associated with the cam 229 on the shaft of the bomb bay selector valve is a single set of contact springs CF.

The sets of contact springs control the circuits of relays disclosed in Fig. 3 which in turn control the fuel pressure motor units which simulate the production of fuel pressures in the fuel flow lines extending to the carburetors of the four engines in response to the operation of engine driven fuel pumps and booster pumps associated with wing and bomb bay tanks in accordance with the settings of the fuel selector valves. The relays also control the circuits of lamps at the instructor's desk to inform the instructor as to the manner in which the selector valves are manipulated to take care of any fuel supply condition which the instructor may impose by the operation of the fuel quantity controls 300, 301, 302 and 303 hereinbefore referred to or by the operation of booster pump failures which the instructor may impose by the operation of switches 400 to 403, inclusive, or by the operation of the circuit breaker throw-out switches 404 to 408, inclusive.

Circuit breaker switches 409 to 413, inclusive, are mounted on the panel at the copilot's station which the copilot may close to operate relays FB1, FB2, FB3, FB4 and ABP to simulate the starting of booster pumps associated with the Nos. 1 to 4 wing tanks and the bomb bay tank.

The fuel pressure motor unit for simulating the production of fuel pressure due to the operation of the fuel pump associated with the simulated No. 4 engine is provided with a reversible alternating current motor 450 which has its stator winding connected across the outer terminals of the secondary winding of transformer T4 and has its rotor winding energizable under the control of relays IFP, DFP, IFP1 and DFP1 from different portions of the secondary winding of transformer T4. The motor through the reduction gear box 451 drives the shaft 452 on which are mounted the cams 453 and 454 for operating the #0 and #17 switches and the gear 455 which, through the gear 456 drives the rotor of the transmitting "autosyn" or synchro-transmitter STR. The transmitter STR is electrically coupled with the synchro-receiver SR which drives the fuel pressure indicator 421 mounted on the instrument panel at the instructor's desk and with a similar synchro-receiver (not shown) which drives a similar fuel pressure indicator mounted on the copilot's instrument panel.

A fuel pressure motor unit similar to that disclosed would be provided to simulate the production of fuel pressure due to the operation of the fuel pumps associated with the simulated Nos. 1, 2 and 3 engines and each such unit would be instrumental in driving other fuel pressure indicators mounted on the instrument panels at the copilot's station and at the instructor's desk. The other indicators at the instructor's desk are illustrated at 418, 419 and 420.

Such portions of the circuits which simulate the operation of the No. 4 engine as are deemed necessary to an understanding of the invention are disclosed schematically in the lower left portion of Fig. 4. For a more complete disclosure of such similar circuits, reference may be had to the application of J. J. Lukacs and W. B. Strickler, Serial No. 542,846, filed January 2, 1944. Similar circuits would be provided to simulate the operation of the Nos. 1, 2, and 3 engines.

The apparatus employed to carry out the present invention having now been described, the functioning of such apparatus to solve different problems will now be discussed. It will be assumed that a flight is to be simulated and that preparatory to the flight, the instructor turns all of the fuel quantity controls 300 to 303, inclusive to positions representative of full wing tanks. It will also be assumed that a full condition of the bomb bay tank is simulated by the operation of control 324.

The navigator first sets the wing tank selector valves of Fig. 2 to their "Tank" position and the bomb bay tank selector valve to its "Off" position. As a result of the setting of the valves, circuits are closed for the T1, T2, T3, and T4 relays, the circuit relay T4 extending, for example, from ground over the contacts of the T switch closed by the cam 228 in the set position of the valve handle 208, thence over conductor 230 and through the winding of relay T4 to battery. With these relays operated obvious circuits are established over their inner upper contacts for the "Tank" lamps at the instructor's desk corresponding to the several selector valves to indicate to the instructor that the valves have been operated to their "Tank" positions. The navigator may also at this time operate the valves associated with the fuel quantity gauges to determine if the wing tanks have their full quantity of fuel. The gauges will function in the manner previously described. The pilot will then close the booster pump switches 409 to 412, inclusive, thereby closing obvious circuits for relays FB1, FB2, FB3 and FB4 in simulation of the starting of the booster pumps associated with the four wing tanks. This would be essential in the operation of an airplane to furnish the necessary fuel pressure at the engine carburetors for priming the engines. The operation of these relays is indicated to the instructor by the lighting of lamps 422 to 425, inclusive.

With these relays operated and fuel supply lines from each of the wing tanks to the carburetors of the associated engines in the operated positions of the fuel selector valves being simulated by the operation of relays T1 to T4, inclusive, circuits are established for the BP relays of the fuel pressure motor units of the four engines, representative of the fact that booster pressure in the fuel lines to the engine carburetors is being simulated. For example the circuit of the BP relay of the motor unit of the No. 4 engine may be traced from ground over the upper front contact of relay FB4, over the back contact of relay 417, over conductor 426, over the upper contacts of relay T4, over conductor 427, through the winding of relay BP to battery. With the fuel quantity controls 300 to 303, inclusive, set to positions representative of full wing tanks, the cams operated by such controls will be operated to cause the closure of their associated sets of contacts thereby establishing circuits for the FS relays of the fuel pressure motor units of the four engines, representative of the fact that fuel is being supplied to the engine carburetors. For example, the circuit of the FS relay of the motor unit for the No. 4 engine may be traced from ground, over the set of contacts 308 closed by cam 307, over the lower contacts of relay T4, over conductor 428 and through the winding of relay FS to battery.

Upon the operation of both relays BP and FS of the motor unit associated with the No. 4 engine, a circuit for the ST relay of such unit is established from ground, over the inner contacts of relay FS, over the lower contacts of relay BP and through the winding of relay ST to battery. Relay ST thereupon operates and establishes a circuit extending from ground over its upper front contacts, over the back contact of relay UL and through the winding of relay IFP to battery. Relay IFP thereupon operates establishing a circuit through the rotor of motor 450 which may be traced from the ground terminal of the secondary winding of transformer T4, through such secondary winding to the 25-volt tap thereof, thence through the rotor winding of the motor and over the front contacts of relay IFP to ground and, since the stator winding of the motor is bridged across the secondary winding of transformer T4, the motor will now operate to turn the shaft 452 in a clockwise direction representative of an increase in the fuel pressure in the fuel line to the carburetor of the No. 4 engine. When the shaft has been rotated to a position representative of a pressure of 17 pounds per square inch, the cam 454 will operate the middle spring of the associated set of contacts to its alternate position thereby establishing a circuit from ground over the inner upper front contact of relay ST, over such cam-operated contacts and through the winding of relay UL to battery which relay upon operating locks to ground over the upper inner front contact of relay ST and at its upper back contact opens the previously traced circuit of relay IFP. Relay IFP thereupon releases to open the rotor circuit of motor 450 and such motor thereupon comes to rest. The rotation of shaft 452 has also been instrumental through gears 455 and 456 in rotating the rotor synchrotransmitter STR thereby causing the synchroreceiver SR to operate and to set the fuel pressure indicator 421 at the instructor's desk and the corresponding indicator (not shown) on the copilot's instrument panel to indicate a fuel pressure of 17 pounds. As soon as shaft 452 moves from normal or the position representative of zero pounds fuel pressure, cam 453 permits the closure of the set of contacts associated therewith thereby establishing an obvious circuit for relay LL.

The fuel pressure motor units (not shown) associated with the Nos. 1, 2 and 3 engines, function in a similar manner thereby causing the fuel pressure indicators 418, 419 and 420 at the instructor's desk and similar indicators on the copilot's instrument panel to indicate similated fuel pressures of 17 pounds in the fuel lines extending to the carburetors of the Nos. 1, 2 and 3 engines.

Upon observing that there is fuel pressure for priming each of the engines, the pilot may now proceed to start each of the engines in the usual order of precedence. To start the No. 4 engine, the pilot closes the ignition switch (not shown) to the "Both" position, thereby establishing the ignition circuit which is simulated in the trainer by the operation of the IGL and IGR relays (Fig. 4). He then operates the priming switch 457 thereby causing the operation of the PRM relay in simulation of the operation of the solenoid operated valve on the carburetor which admits raw fuel from the carburetor to the intake manifolds of the top cylinders of the engine. With relay LL previously operated representative of the pressure of fuel at the carburetor of the No. 4 engine, the operation of relay PRM establishes a circuit from ground over the contacts thereof, over the inner lower front contact of relay LL and through the winding of relay PRM1 which operates and in turn causes the operation of relay PRM2. Relay PRM2 upon operating locks over its inner lower contacts to ground at the lower back contact of relay EST1.

When the starter switch (not shown) is now operated, and the turning over of the engine under the starter control is simulated, the relay RPM becomes operated, establishes an obvious circuit for the RPM relay 458 in the fuel pressure motor unit No. 4 engine and, with the engine primed as represented by the operated relay PRM2 and furnished with ignition as represented by the operated relays IGL and IGR, a circuit is established for relay EST. This circuit may be traced from ground, over the contacts of relays IGL and IGR, over contacts of the engine disable key 460 at the instructor's desk, over the lower contacts of relay LL, over the lower contacts of relay PRM2, over the upper contacts of relay RPM and through the winding of relay EST to battery. Relay EST operates to simulate the starting of the engine and causes the operation of relay EST1 which in turn causes the operation of the EST relay 459 in the fuel pressure motor unit for the No. 4 engine. Relay EST1 also opens the locking circuit of the PRM2 relay which now releases since its initial operating circuit was opened by the release of relays PRM and PRM1 when the pilot released the momentarily operated priming switch 457.

The release of relay PRM2 would release relay EST and therefore, to maintain the simulation of the engine as running under throttle control, it is necessary for the pilot to operate the mixture control (not shown) from the idle cut-off position in which relay ICO1 is operated to the automatic rich position in which relay ICO1 is released. The release of relay ICO1 thereby bridges the lower contacts of relay PRM2, thus maintaining an operating circuit for relay EST whereby it is held operated and maintains relay EST1 operated.

Relay ST of the fuel pressure motor unit is now held operated irrespective of the continued operation of relay BP over a circuit which may be traced from ground, over the outer contacts of relay FS, over the contacts of the EST relay 459, over the contacts of the RPM relay 458 and through the winding of relay ST to battery and continues to remain operated so long as the engine is operating under throttle control as will be represented by the continued operation of both relays 458 and 459. If the engine is turned off when the airspeed of the simulated flight is in excess of 50 knots, the AS relay 461 of the engine control circuit will be operated. The EST relay 459 will release but the RPM relay 458 will continue to be operated since the simulated engine will be assumed to be turning over due to the wind milling action of its propeller. With the relay 461 and relay 458 operated, the circuit of relay ST is still established from ground over the outer contacts of relay FS, over the contacts of relay 461, the contacts of relay 458 and through the winding of relay ST to battery.

The simulation of the starting of the other engines is accomplished in the manner just described for the No. 4 engine. After take-off of the flight has been accomplished, the booster pump switches 409 to 412, inclusive, may be opened, thereby causing the release of the BP relays in the fuel pressure motor units.

Controls are provided at the instructor's desk by means of which the instructor may increase or decrease the fuel pressure. If the instructor operates the control 403 to the DEC position to decrease the fuel pressure in the fuel line to the carburetor of the No. 4 engine, a circuit is established from ground thereover, over the upper contacts of relay LL and through relay DFPI to battery thereby causing the latter relay to operate to establish a circuit form the 25-volt tap of the secondary winding of transformer T4, through the rotor circuit of the motor 450, over the upper back contacts of relays IFP, DFP and IFPI and over the front contacts of relay DFPI to the 35-volt tap of the secondary winding of transformer T4. The motor 450 will now run at a slow speed in a direction representative of a reduction in fuel pressure so long as the instructor holds the control 403 closed or if held closed long enough until cam 453 operates the set of contacts associated therewith to release LL and thereby release relay DFPI to stop the motor. The fuel pressure indicators at the pilot's station and at the instructor's desk will show the decreasing pressure at a slow enough rate to avoid attracting the attention of the copilot too suddenly.

If the simulated pressure is reduced below seventeen pounds, the cam 454 releases the contact set associated therewith. To bring the pressure back to seventeen pounds the copilot should close the booster pump switch 412 thereby reoperating relay BP. A circuit will now be established from ground over the inner upper front contact of relay ST, over the normal set of contacts of the contact associated with cam 454, over the contacts of relay BP and through the winding of relay ULB to battery. Relay ULB will thereupon operate and establish an obvious circuit for relay IFP which will again establish the previously traced circuit of motor 450 to cause such motor to turn shaft 452 in a direction representative of an increase in pressure or until cam 454 again operates the set of contacts associated therewith to open the circuit of relay ULB and to thereby release relay IFP to stop the motor 450. While the relay IFP is operated, the operation of relay DFPI by the continued operation of the control 403 at the instructor's desk is rendered ineffective. When the fuel pressure has been increased to the desired amount, the copilot restores the booster pump switch 412.

The instructor may increase the fuel pressure by operating the control 403 to the INC position in which a circuit is established from ground over the contacts of such control, over the lower contacts of relay ST and through the winding of relay IFPI to battery. Relay IFPI upon operating establishes a circuit from the 25-volt tap of the secondary winding of transformer T4, through the rotor circuit of the motor 450, over the upper back contacts of relays IFP and DFP and over the front contacts of relay IFPI to the 15-volt tap of the transformer winding whereupon the motor will run at slow speed in a direction to increase the fuel pressure indication so long as the instructor maintains the control 403 operated. The instructor will not cause an increase of indicated fuel pressure in excess of twenty-five pounds.

It will now be assumed that the simulated flight has reached an altitude of 10,000 feet at which the fuel booster pumps should be started. The copilot thereupon operates the booster pump switches 409 to 412, inclusive, thereby causing the operation of the BP relays of the fuel pressure motor units in the manner previously described. As the simulated flight proceeds, the instructor from time to time will adjust the fuel quantity controls 300 to 303, inclusive, in a manner representative of the consumption of fuel from the wing tanks. The navigator will, in a manner previously described, check the quantity of fuel in the tanks from time to time.

In the flight of an airplane it may be that one of the engines will consume fuel at a faster rate than the other engines, as for example when it runs at a higher cylinder temperature and the pilot attempts to keep it cool by adjusting its mixture control to automatic rich. This might result towards the end of a long flight in the consumption of all of the fuel in the tank normally supplying that engine so that the engine would cease to receive fuel and would slow down to a speed determined only by the wind-milling action of its propeller. To restart the engine it would be necessary to take steps to transfer fuel from one of the other wing tanks to the empty tank. To simulate this condition in the trainer, the instructor for example, will set the fuel quantity control 303 for the right outboard or No. 4 wing tank to a position representative of a total consumption of fuel from such tank, thereby causing cam 307 to open the set of contacts 308 and thus open the previously traced circuit of the FS relay in

the fuel pressure motor unit for the No. 4 engine. Relay FS upon releasing opens the circuit of relay ST which releases and closes a circuit from ground over its inner upper back contact, over the inner upper contacts of relay LL and through the winding of relay DFP to battery. Relay DFP will thereupon operate and establish a circuit from the 25-volt tap of the secondary winding of transformer T4, through the rotor winding of motor 450, over the upper back contact of relay IFP, over the front contacts of relay DFP and to the 50-volt tap of the transformer. Motor 450 will thereupon rotate the shaft 452 in a direction representative of a reduction in fuel pressure until the cam 453 opens the set of contacts associated therewith to release relay LL whereupon the circuit of relay DFP is opened and the motor stops. The fuel pressure indicator 421 at the instructor's desk and the corresponding indicator at the copilot's station will now have been set to indicate zero fuel pressure for the No. 4 engine.

The copilot noting the slowing down of the engine as indicated by the tachometer reading and the reduction of fuel pressure will instruct the navigator, for example, to transfer fuel from the left outboard or No. 1 wing tank to the right outboard or No. 4 wing tank in an endeavor to restart the No. 4 engine. The navigator will then operate the fuel selector valve for the Nos. 4 and 1 tanks to their "Tank-cross feed" positions and the copilot will open the booster pump switch 412 allocated to the No. 4 tank so that the No. 4 tank may be filled from the cross feed manifold. With the engine not firing and turning over only at a speed determined by the windmilling action of its propeller, relay 459 of the fuel pressure motor unit will be released but relay 458 will remain operated.

With the Nos. 1 and 4 selector valves set into their "Tank-cross feed" positions, the T-CF switches associated therewith become closed resulting in the establishment of circuits from ground thereover, over conductors 231 and 232 and through the windings of relays TD4 and TD1 to battery. Thereupon such relays operate and close obvious circuits over their lower contacts for the "Tank" lamps at the instructor's desk allocated to the right outboard and left outboard or the Nos. 4 and 1 tanks, respectively, and also close obvious circuits over their upper contacts for the "Cross" lamps at the instructor's desk allocated to the Nos. 4 and 1 tanks respectively. The "Tank" and "Cross" lamps appertaining to each of these tanks being both lighted, the instructor is apprised of the fact that the Nos. 4 and 1 fuel selector switches have been operated to their "Tank-cross feed" positions. With the booster pump switch 412 now opened and the booster pump switch 409 still operated, the circuit for relays BP of the fuel pressure motor unit for the No. 4 engine extends from ground over the upper contacts of relays FB1 and 414, over conductor 429, over the middle upper contacts of relay TD1, over the inner upper contacts of operated relay TD4 and over conductor 427 through the winding of relay BP to battery.

A new circuit for relay FS is now established from ground over the contacts 323 associated with the fuel quantity control 300 for the left outboard wing tank, over the middle lower front contact of relay TD1, over the inner lower contacts of relay TD4, over conductor 428 and through the winding of relay FS to battery. Relay FS now operates representative of the resumption of fuel supply to the carburetor of the No. 4 engine. At the same time the FS relay of the fuel pressure motor unit for the No. 1 engine is maintained operated from ground supplied over contacts 323 and over the lower middle and inner contacts of relay TD1. With relay BP operated, the reoperation of relay FS reestablishes the circuit of relay ST from ground over the inner contacts of relay FS, over the lower contacts of relay BP and through the winding of relay ST to battery. Relay ST now establishes the previously traced circuit for relay IFP over the upper back contact of relay UL which released when relay ST released and the shaft 452 rotated to the position representative of zero fuel pressure and restored the set of contacts operated by cam 454 to its normal position. Relay IFP now causes the operation of motor 450 until the shaft 452 reaches a position representative of seventeen pounds fuel pressure when relay UL again operates and locks under the control of relay ST and opens the circuit of relay IFP. The engine should now start as will be evidenced by the tachometer reading. At this time relay 459 will reoperate to establish a new holding circuit for relay ST.

The instructor will then reset the fuel quantity controls 300 and 303 to show a replenishment of fuel in the No. 4 or right outboard tank and the corresponding diminution of fuel in the No. 1 or left outboard tank due to the transfer of fuel from such tank to the No. 4 or right outboard tank. The navigator may check the assumed fuel quantities in these tanks in the manner previously described. Upon the resetting of the control 303 the contacts 308 are again closed so that when the navigator restores the fuel selector valves allocated to Nos. 1 and 4 tanks to their "Engine-tank" positions thereby reoperating relays T1 and T4 and releasing relays TD1 and TD4, the FS relays of the fuel pressure motor units for the Nos. 1 and 4 engines are again held operated over the previously traced circuits. At this time the lighted "Cross" lamps at the instructor's desk will become extinguished and all the "Tank" lamps will be lighted to indicate that all of the selector valves are now set in their "Engine-tank" positions.

It will now be assumed that the No. 4 or right outboard tank loses its fuel supply due to leakage as may be simulated in the trainer by the movement of control 303 to its tank empty position. As previously described, this will result in the release of relay FS of the fuel pressure motor unit for the No. 4 engine, the resultant operation of the shaft of such motor unit to a position representative of the reduction of fuel pressure to zero and the stopping of the engine as will be represented by the release of relay 459. If the copilot is aware of the condition of the No. 4 tank, he will open the booster pump switch 412 and inform the navigator that the No. 4 tank selector valve should be set to its "Engine-cross feed" position and that the No. 1 tank selector valve should be set to its "Tank-cross feed" position, in order that the No. 4 engine may receive fuel from the No. 1 tank over the cross feed manifold while the No. 1 engine continues to receive fuel from the No. 1 tank. With these valve settings no fuel will be pumped into the leaking No. 4 tank.

With the selector valves set as above described, relay TD1 is operated as previously described and relay D4 is now operated in a circuit from ground over the CF contact set closed by the setting of the No. 4 selector valve, over conductor 233 and through the winding of relay D4 to battery. The setting of the No. 4 selector valve released relay T4 thereby extinguishing the "Tank" lamp and with the D4 relay now operated a circuit is established over its inner upper contacts and through the "Cross" lamp to battery to inform the instructor that the selector valve has been reset to its "Engine-cross feed" position. With relay TD1 operated, both the "Tank" and "Cross" lamps allocated to the No. 1 tank will light to inform the instructor that the No. 1 selector valve is in its "Tank-cross feed" position.

The circuit for the BP relay of the fuel pressure motor unit for the No. 4 engine will now be established from ground applied by relay FB1 through the operation of switch 409 to conductor 429, thence over the middle upper contacts of relay TD1, over the middle upper contacts of relay D4 and over conductor 427 through the winding of relay BP to battery. The FS relay will be reoperated over a circuit from ground over the contacts 323, over the middle lower contacts of relay TD1, over the lower contacts of relay D4 and over conductor 428 through the winding of relay FS to battery. Relays BP and FS will now function as previously described to cause the fuel pressure motor unit to function in a manner representative of a restoration of fuel pressure to the No. 4 engine carburetor. The No. 4 engine should now start and reoperate relay 459 as previously described.

It will now be assumed that the Nos. 2, 3 and 4 wing tanks become empty as would be simulated by the operation of the controls 301, 302 and 303 to their empty positions and the consequent opening of the cam operated contacts controlled by such controls. This would result in the release of the operated FS relays of the fuel pressure motor units for the Nos. 2, 3 and 4 engines and the consequent operation of the fuel pressure motor units to positions representative of the failule of fuel pressure at the carburetors of the Nos. 2, 3 and 4 engines with the stoppage of such engines. Under this condition the copilot would open all of the booster pump switches 409 to 412, inclusive, allocated to the wing tanks, close the booster pump switch 413 to simulate the starting of the booster pump associated with the bomb bay tank and inform the navigator to set the Nos. 2, 3 and 4 selector valves and the booster tank valve into their "Engine-cross feed" positions and the No. 1 tank selector valve into its "Tank-cross feed" position in which all four engines would receive fuel over the cross feed manifold from the bomb bay tank and the No. 1 wing tank. The closure of the bomb bay booster pump switch causes the operation of relay ABP which in turn causes the lighting of lamp 431 at the instructor's desk to inform the instructor that the bomb bay booster switch has been operated.

With the valves thus set the D2, D3, and D4 relays would be operated over circuits established by the closure of the TF contacts associated with the Nos. 2 to 4 tank selector valves and relay TD1 would be operated over a circuit established by the closure of the T-CF contact set associated with the No. 1 tank selector valve. The closure of the contacts associated with the bomb bay tank selector valve establishes a circuit over conductor 234 and through the winding of relay BT to battery. Relay BT operates and establishes an obvious circuit through the "Bomb bay" lamp to battery to inform the instructor of the operation of such valve. The operation of relays D2, D3 and D4 also closes obvious circuits over their inner upper contacts for the "Cross" lamps to inform the instructor that the Nos. 2 to 3 tank selector valves have been set to their "Engine-cross feed" positions and the operation of relay TD1 establishes circuits as previously traced for the "Cross" and "Tank" lamps allocated to the No. 1 tank to apprise the instructor that the No. 1 tank selector valve has been set to the "Tank-cross feed" position.

With relays TD1, D2, D3 and D4 operated, a circuit is effective to maintain all of the FS relays operated which may be traced from ground over the contacts 323 associated with the fuel quantity control for the No. 1 tank, over the inner and middle lower contacts of relay TD1 to the FS relay of the fuel pressure motor circuit associated with the No. 1 engine and also over the lower contacts of the operated D2, D3 and D4 relays to the FS relays of the fuel pressure motor units associated with the Nos. 2, 3, and 4 engines. The FS relay of the fuel pressure motor unit for the No. 1 engine being thus maintained operated, the fuel pressure unit for that engine will continue to remain in the condition representative of the maintenance of fuel pressure at the carburetor of the No. 1 engine. The reoperation of the FS relays of the fuel pressure motor units for the Nos. 2, 3 and 4 engines will now cause such fuel pressure motor units to function in a manner representative of the restoration of fuel pressure at the carburetors of the Nos. 2, 3 and 4 engines in the manner previously described. The Nos. 2, 3 and 4 engines should now restart.

It will now be assumed that all of the wing tanks become empty as would be simulated by the operation of controls 300 to 304, inclusive, to their empty positions and the consequent opening of the cam operated contact sets controlled by such controls. This would result in the release of all of the operated FS relays of the fuel pressure motor units and the consequent operation of such units to positions representative of the failure of fuel pressure at the carburetors of the four engines with the resultant stopping of such engines. Under this condition the copilot would open all of the booster pump switches 409 to 412 inclusive allocated to the four wing tanks, close the booster pump switch 413 to simulate the starting of the booster pump associated with the bomb bay tank and inform the navigator to set the wing tank selector valves and the booster tank selector valve into their "Engine-cross feed" positions.

With the valves thus set the BT, D1, D2, D3 and D4 relays are all operated over circuits established by the closure of the CF contacts associated with such valves. The operation of these relays establishes obvious circuits for the "Bomb bay" and "Cross" lamps at the instructor's desk to inform the instructor that the selector valves have all been operated to their "Cross feed" positions to enable fuel to flow from the bomb bay tank to the four engines. With the BT, D1, D2, D3, D4 and ABP relays operated, a circuit is established from ground serially over the outer upper front contacts of relays D1, D2, D3 and D4, over conductor 432, over the lower contacts of relay ABP, over conductor 433, over the inner lower contacts of relay BT, thence in parallel over the middle upper contacts of relays D1, D2, D3 and D4 and through the windings of the BP relays of all of the fuel pressure motor units to battery. For example, the circuit of relay BP of the fuel pressure motor unit for the No. 4 engine may be traced from the middle upper contacts of relay D4 over conductor 427 and through relay BP to battery. A circuit is also established from ground serially over contacts of relays D1, D2, D3 and D4, thence over conductor 432, over the set of contacts 325 operated by cam 326 of the bomb bay fuel quantity control 324 at the instructor's desk, over the lower contacts of relay BT and in parallel over the lower contacts of relays D1, D2, D3 and D4 and through the windings of the FS relays of all of the fuel pressure motor units to battery. For example the circuit of relay FS of the fuel pressure motor unit for the No. 4 engine may be traced from the lower contacts of relay D4, over conductor 428 and through relay FS to battery. Since the FS relays of the fuel pressure motor units are thus reoperated, the motor units are caused to function in a manner representative of the restoration of fuel pressure at the carburetors of the four engines in the manner previously described and the engines should now restart.

The instructor may simulate failure of any of the wing tank booster pumps by the operation of the corresponding switches 400 to 403, inclusive, to their "Fuel pump off" position. For example, to simulate the failure of the fuel pump for the No. 4 or right outboard wing tank, the instructor would operate the switch 403, thereby establishing a circuit over the right contacts of such switch through the winding of booster pump cut-off relay 414. The operation of relay 417 removes operating ground from the circuit over which the BP relay of the fuel pressure motor unit for the No. 4 engine may be operated thus preventing the operation of such relay when the copilot closes the booster pump switch 412.

The instructor may simulate the blowing of any one of the booster pump circuit breaker switches 400 to 413, inclusive, by closing one of the appropriate keys 404 to 408, inclusive. For example the closure of key 404 establishes a circuit from full battery through the thermal circuit breaker switch 409 to ground thereby causing such switch to open and to release the associated relay FB1. Relay FB1 upon releasing opens the circuit of lamp 422 which becomes extinguished as a signal that the booster pump is not functioning and closes the circuit of lamp 430 which thereupon lights. When the pilot has taken steps to restore the circuit breaker switch, the lamp 430 becomes extinguished as a signal to the instructor that the pilot has corrected the circuit difficulty.

What is claimed is:

1. In a ground trainer for simulating the fuel distribution system of an airplane of a type having a plurality of engines, a plurality of fuel tanks, a fuel pressure booster pump associated with the outlet of each of the tanks and a plurality of fuel selector valves through which fuel from the tanks may be distributed to the engines, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, switching means operable in simulation of the operation of the selector valves, means for simulating the operation of the booster pumps, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, means effective to cause the operation of said latter means when said fuel quantity and booster pump simulating means and said switching means have been operated in a manner representative of the supply of fuel under pressure

from the tanks to the simulated engines, and means controlled by each fuel pressure simulating means for enabling the simulation of the starting of the simulated engine with which it is associated.

2. In a ground trainer for simulating the fuel distribution system of an airplane of a type having a plurality of engines, a plurality of fuel tanks, a fuel pressure booster pump associated with the outlet of each of the tanks, and a plurality of fuel selector valves through which fuel from the tanks may be distributed to the engines, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, switching means operable in simulation of the operation of the selector valves, means for simulating the operation of the booster pumps, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, means effective to cause the operation of said latter means in a manner representative of the supply of fuel under pressure from tanks for priming simulated engines when said fuel quantity and booster pump simulating means and said switching means have been operated in a manner representative of the supply of fuel under pressure from the tanks to the simulated engines, and means controlled by each fuel pressure simulating means for simulating the priming and starting of the simulated engine with which it is associated.

3. In a ground trainer for simulating the fuel distribution system of an airplane of a type having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks and a plurality of fuel selector valves through which fuel from the tanks may be distributed to the engines, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, switching means operable in simulation of the operation of the selector valves, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, means in each fuel pressure simulating means controlled from the associated engine simulating means representative of the operation of the engine driven fuel pump, and means effective to control the operation of said fuel pressure simulating means under the joint control of said fuel quantity simulating means, of said switching means and of said engine driven pump simulating means.

4. In a ground trainer for simulating the fuel distribution system of an airplane of a type having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks, a plurality of fuel selector valves through which fuel from the tanks may be distributed to the engines, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, switching means operable in simulation of the operation of the selector valves, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, means controlled from the associated engine simulating means representative of the operation of the engine driven fuel pump, means in said engine simulating means operable if the simulated flight has attained air speed above a predetermined minimum, and means effective to control the operation of each fuel pressure simulating means under the joint control of said fuel quantity simulating means, of said switching means and of the engine driven pump simulating means and of the air speed simulating means of the simulated engine with which it is associated.

5. In a ground trainer for simulating the fuel distribution system of an airplane of a type having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks and a plurality of fuel selector valves through which fuel from the tanks may be distributed in the engines, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, switching means operable in simulation of the operation of the selector valves, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, means in each of said fuel pressure simulating means controlled from the associated engine simulating means representative of the operation of the engine driven fuel pump and representative of the operation of the engine under throttle control, and means effective to control the operation of each fuel pressure simulating means under the joint control of said latter means, of said fuel quantity simulating means and of said switching means.

6. In a ground trainer for simulating the fuel distribution system of an airplane of a type having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks and a plurality of fuel selector valves through which fuel from the tanks may be distributed to the engines, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, switching means operable to simulate the operation of the selector valves, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, a first relay controlled from the associated engine simulating means when the operation of the engine throttle control is simulated, a second relay controlled from the associated engine simulating means whenever the simulated engine is rotating either under throttle control or through the windmilling action of its propeller, a third relay operable under the joint control of said fuel quantity simulating means and of said switching means and a start relay under the control of said first, second and third relays to control the operation of said fuel pressure simulating means.

7. In a ground trainer for simulating the fuel distribution system of an airplane having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks, a fuel pressure booster pump associated with the outlet of each of the tanks and a plurality of fuel selector valves through which fuel from the tanks may be distributed to the engines, means for simulating the presence of fuel in each tank, means for simulating the operation of each of the engines, switching means operable in simulation of the operation of the selector valves, means for simulating the operation of booster pumps, means associated with each of said engine simulating means for simulating the production of fuel pressure at the carburetor of such engine, an instructor's desk, means controlled from said desk to cause said latter means to operate to a position representative of a decrease

in fuel pressure, a relay controlled jointly by said fuel quantity simulating means and said switching means representative of the availability of fuel, a relay responsive to the operation of said booster pump simulating means and said switching means representative of booster pump operation and means controlled jointly by said relays to control said fuel pressure simulating means to a position representative of an increase in fuel pressure, said latter means while operated preventing the control of said fuel pressure simulating means from said instructor's desk in a manner representative of a decrease in fuel pressure.

8. In a ground trainer for simulating the fuel distribution system of an airplane having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks, a fuel pressure booster pump associated with the outlet of each of the tanks, and a plurality of fuel selector valves each operable into one position for associating one engine carburetor solely with a tank allocated thereto, operable into a second position for associating said one engine carburetor and allocated tank with a cross feed manifold and operable into a third position for associating said one engine carburetor solely with the cross feed manifold, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, means for simulating the operation of booster pumps, means associated with each engine simulating means for simulating fuel pressure at the carburetor of such engine, and switching means selectively operable in simulation of the operation of the selector valves to render said fuel pressure simulating means operable under the control of said fuel quantity booster pumps and engine simulating means to represent fuel pressure at the engine carburetors if said selector valves are so set that in the actual airplane fuel would flow from one or more of the tanks to the carburetors of any of the engines.

9. In a ground trainer for simulating the fuel distribution system of an airplane having a plurality of engines, a fuel pressure pump associated with each of the engines, a plurality of fuel tanks, a fuel pressure booster pump associated with the outlet of each of the tanks and a plurality of fuel selector valves for associating engine carburetors with tanks, and with a cross feed manifold or engine carburetors with the cross feed manifold, means for simulating the presence of fuel in each of the tanks, means for simulating the operation of each of the engines, means for simulating the operation of booster pumps, means associated with each engine simulating means for simulating fuel pressure at the carburetor of such engine, and relays selectively operable in the several selecting positions of the valves to render said fuel pressure simulating means operable under the control of said fuel quantity booster pumps and engine simulating means to represent fuel pressure at the engine carburetors if said selector valves are so set that in an actual airplane fuel would flow from one or more of the tanks to the carburetors of any of the engines.

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