June 10, 1947. J. VOLIAZZO ET AL 2,421,768

FUEL FLOW WARNING DEVICE

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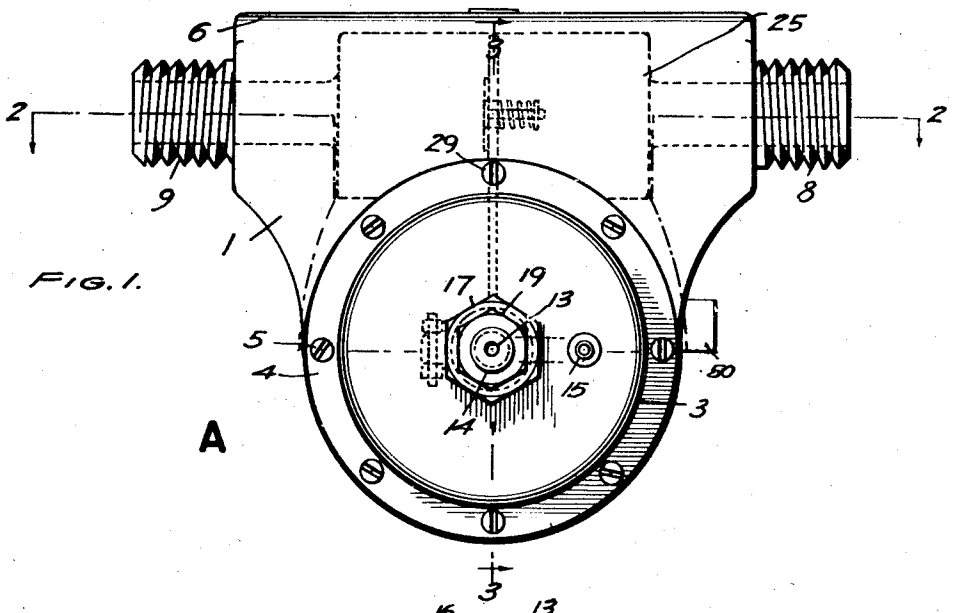


FIG. 1.

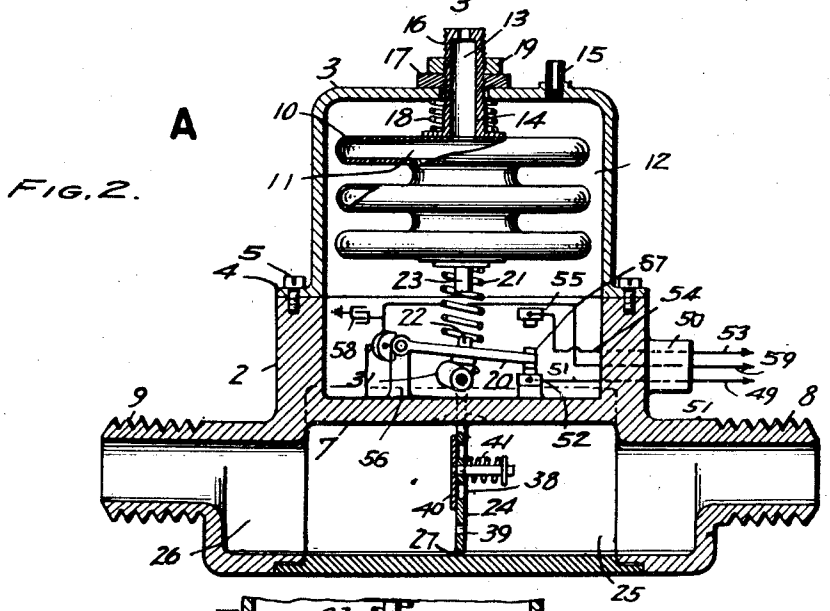


FIG. 2.

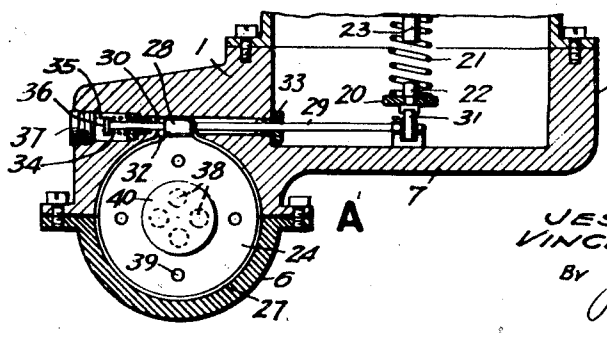


FIG. 3.

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FUEL FLOW WARNING DEVICE

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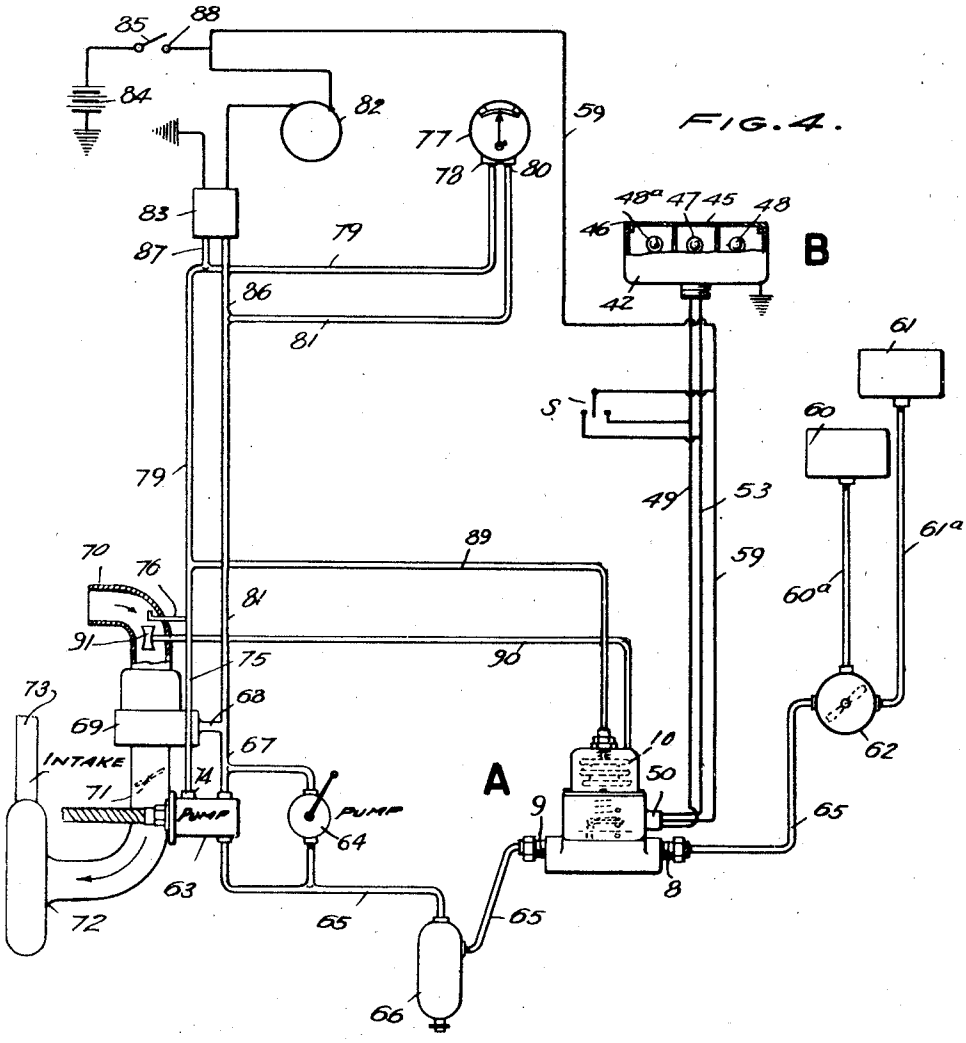


FIG. 4.

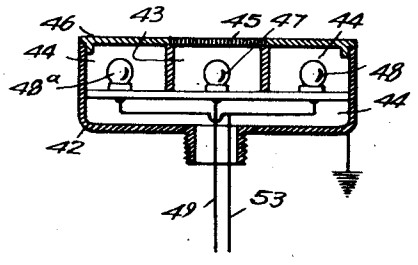


FIG. 7.

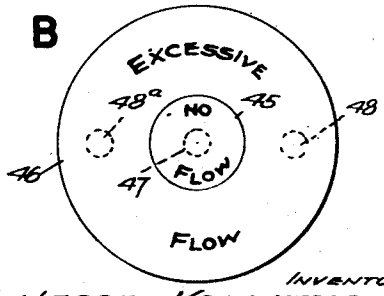


FIG. 8.

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FUEL FLOW WARNING DEVICE

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FIG. 5.

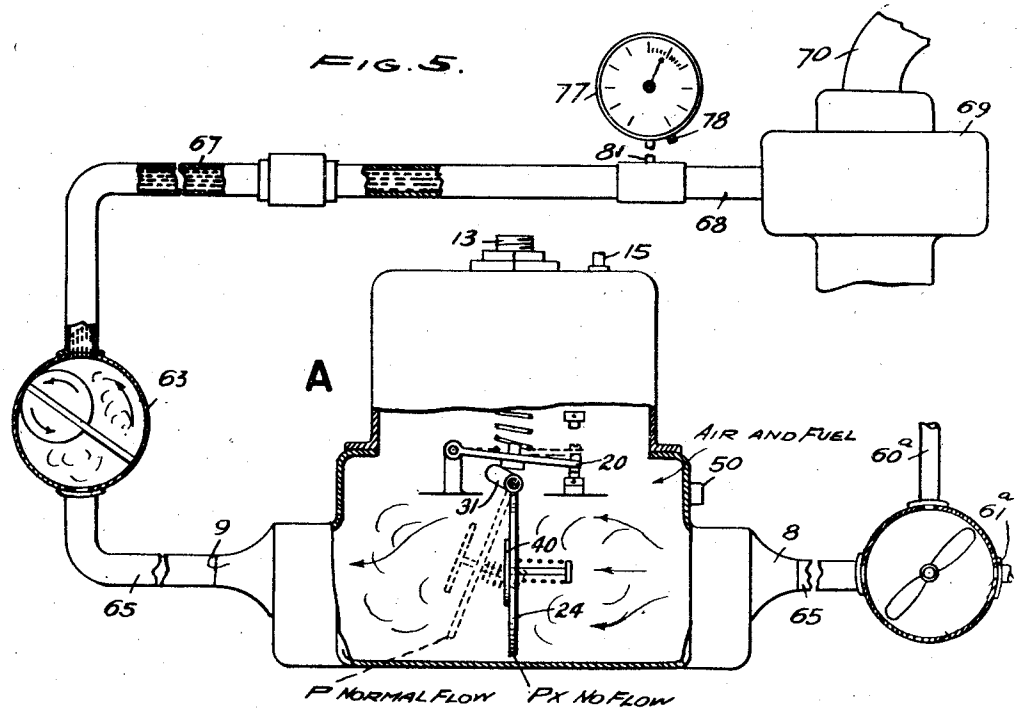
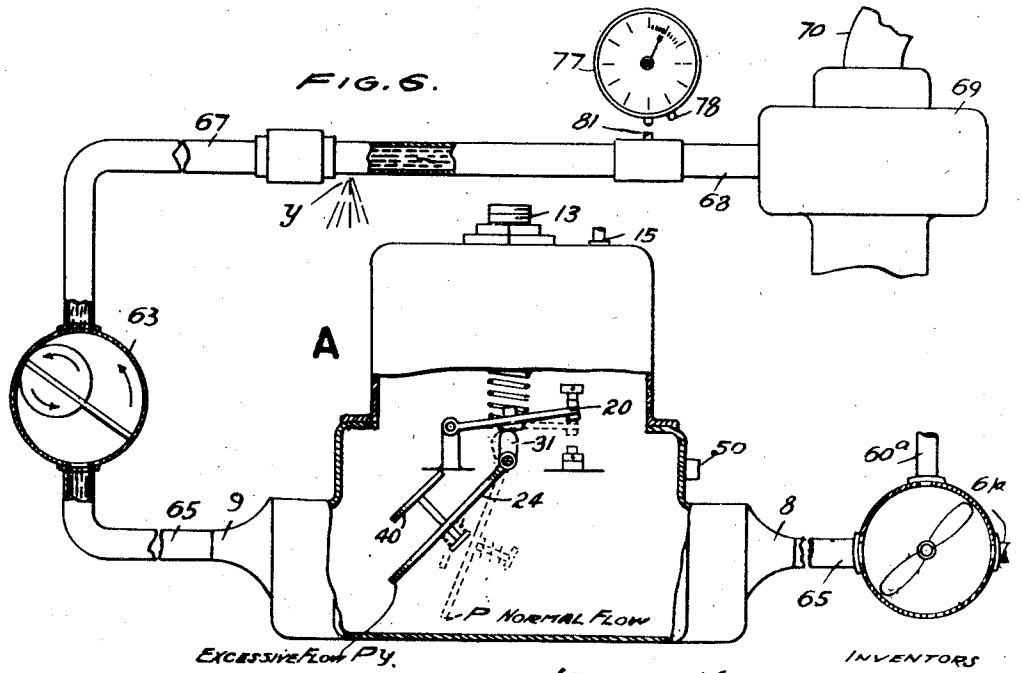


FIG. 6.



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UNITED STATES PATENT OFFICE

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FUEL FLOW WARNING DEVICE

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Application June 29, 1945, Serial No. 602,244

9 Claims. (Cl. 177—311)

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

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

This invention relates to a fuel flow warning device for use with an aircraft engine fuel system to give adequate warning of fuel system failure.

Typical aircraft fuel system circuits include a fuel-pressure gage and a fuel-pressure drop warning signal, with actuating mechanisms varied to fuel pressure on one side and to carburetor air pressure on the other side, to give a continuous indication of the functioning of the system. These indicators, being responsive only to variation in the fuel pressure between the discharge side of the fuel pump and the carburetor or injector, do not give adequate warning of fuel system failure due to conditions or malfunctioning not proximately affecting the fuel pressure on the high pressure side of the fuel pump. Since the conventional fuel pump is designed to deliver the required volume of fuel to the carburetor or injector at a constant discharge pressure under all conditions and for a considerable period after exhaustion of fuel at the supply tank, the fuel pressure is independent of the fuel flow rate and remains unchanged regardless of variations in the fuel flow. Hence, variations in fuel flow disproportionate to the requirements of the system for normal engine operation, such as results from leaks in the pressure side of the system or malfunctioning of the carburetor or injector, may occur and exist for some time without change in fuel pressure and with no indication thereof by either the fuel-pressure gage or the fuel-pressure warning signal.

When such equipped fuel systems malfunction under extreme operating conditions, the operator of the aircraft is without any warning or preindication of fuel system failure in time sufficient to take corrective action to prevent engine failure. The correction period (i. e., the time interval between the warning signal and the actual failure of the system from fuel exhaustion or other malfunctions) afforded by the fuel-pressure gage and warning signal lamp of the conventional fuel system is approximately thirty seconds or less dependent upon the rate of fuel consumption of the engine at the time of the signal warning. At times, engine failure may occur practically upon signal warning as in systems with carburetors which require continuous pressure to discharge the fuel and which cut out quickly after the initial drop in fuel pressure.

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On such systems, the warning signal does not give adequate warning of fuel system failure.

It is an object of the present invention, therefore, to provide a warning device for engine fuel systems which will not only afford a correction period of greater duration than that given by the commonly employed fuel-pressure gage and fuel-pressure-drop warning signal but also give adequate warning of conditions of excessive and decreased fuel flow detrimental to the proper functioning of the fuel system but not indicated by the aforementioned fuel-pressure gage or fuel-pressure-drop warning signal.

Another object of the invention is to provide a warning device for engine fuel systems in which the rate of fuel flow in the system is compared with the fuel flow-rate necessary to meet the fuel consumption requirements of the engine for different normal conditions of engine-operation and which will give adequate warning of fuel flow in excess of and below the required flow-rate.

A further object of the invention is to provide a fuel flow warning device which is readily adaptable to all types of fuel pressure systems and which also can be co-ordinated with the fuel-pressure gage and pressure drop warning signal, or other safety complements, of aircraft fuel systems for reducing the hazards of fuel system failures and providing additional safety in the operation of aircraft.

The objects and advantages of the invention are attained by the novel construction and incorporation in an engine fuel-feeding system of a fuel flow warning device which, briefly described, comprises opposed force-exerting means, one of which is responsive to mass air flow to the engine to exert a force which is a reference or measure of the required rate of fuel flow to the engine for a given engine speed and the other of which is responsive to the fuel flow pressure in the pump induction side of the system for exerting a force which is a reference or measure of the instant rate of fuel flow to the pump, in combination with a fuel flow indicator including a movable member operatively connected with the opposed force-exerting means to be maintained in a given position indicative of a normal fuel flow when the opposed forces are equal and to be deflected to positions at relatively opposite sides of the given position in accordance with an unbalanced relationship between the forces resulting from supernormal or subnormal fuel flow.

A practical embodiment of the invention is illustrated in the accompanying drawings, wherein:

Figure 1 is a top plan view of the signal-control unit of the invention.

Figure 2 is a vertical longitudinal sectional view of the signal-control unit housing and associated mechanism taken on line 2—2 of Figure 1.

Figure 3 is a vertical transverse sectional view on line 3—3 of Figure 1.

Figure 4 is a schematic view of the essential units and circuits of a typical single engine airplane fuel system with the device of the invention incorporated therein.

Figure 5 is a schematic view of the fuel system and signal-control unit installation illustrating the reaction of the unit to fuel system failure characterized by decreased fuel flow.

Figure 6 is a schematic view similar to Figure 5 but illustrating signal-control unit reactance to fuel system failure characterized by excessive fuel flow.

Figure 7 is a detail sectional view of the signal unit.

Figure 8 is a top plan view of the signal unit.

The fuel flow warning device of the invention comprises essentially a signal-control unit A and a signal unit B. The mechanism of the signal-control unit A is housed within a body having an air section and a fuel section separated by an intervening wall or partition 1. In the construction shown in Figures 1 to 3 inclusive, the air section is defined by a comparatively shallow-cup-shaped body portion 2 and a high dome or cover 3 with bottom flange 4 supported on and fastened in leak-proof relation with the upper edge of the body portion 2, as by screws 5, whereas the fuel section is defined by a lateral tubular body portion 6 forming a fuel conduit offset from and depending below the bottom wall 7 of the air section; the end portions 8 and 9 at the inlet and outlet ends of the fuel conduit being reduced in diameter and externally screw-threaded as shown for connection into a fuel system circuit.

The air section is divided into two chambers by a pressure-sensitive bellows 10 contained within the domed cover 3; the space 11 on the inside of the bellows forming one chamber and the space 12 outside of the bellows forming the other chamber. A vent 13 for the chamber 11 is provided in a stem 14 at the upper end of the bellows, and a vent 15 for the chamber 12 is provided in the top of the cover 3. The bellows-stem 14 has an externally screw threaded portion 16 which protrudes through a non-threaded orifice in the top of the cover 3. A nut 17 carried by the stem 14 and in abutment with the top surface of the cover supports the stem and bellows in suspension within the chamber 12; contact between the cover and the nut being maintained by the downward thrust of a bellows-tensioning spring 18 encircling the stem 14 and in compression between the top of the bellows and the overhanging underside of the cover. A lock nut 19 is also provided on the stem 14. The force exerted by the bellows in response to a pressure difference between chambers 11 and 12 is applied to a movable member 20 through a suitable medium 21. In the construction shown, the member 20 is a horizontally disposed switch arm of a lamp-circuit switch mechanism housed within the body portion 2 in spaced relation to the overhanging bottom of the bellows, and the medium 21 is a helical spring extending vertically between the switch arm and the bottom of the bellows with its lower end secured by a keeper 22 on the switch arm and its upper end secured by a keeper 23 on the bellows. Adjustment and regulation of the initial tension on the spring 21 is obtained by raising or lowering the bellows and this is effected by proper turning of the bellows-adjusting nut 17 on the threaded stem 14.

The fuel section houses a circular disk or impeller 24 within an enlarged central chambered portion 25 of the fuel flow passage 26, the respective diameters of the impeller and impeller-chamber being such as to provide slight clearance 27 at the periphery of the impeller when the latter is in a plane perpendicular to the axis of the impeller chamber. The impeller is attached at 28 to a shaft 29 journaled in a cross-bore 30 at the top of the impeller chamber; the shaft extending into the air section and carrying a cam 31 engaged with the underside of the switch arm 20. The cross-bore is open to the impeller chamber through an orifice 32 and leakage at the inner or air section end of the cross-bore is prevented by a suitable shaft seal 33. A spring 34 encircles the shaft at its outer end and is housed within an enlargement 35 of the cross-bore with one end seated on the bottom of the housing and its other end engaging a stop 36 on the shaft. The spring housing 35 is provided with a screw-threaded closure plug 37. Flow of fuel through the impeller is provided for by one or more ports 38 in the central portion of the impeller and smaller ports or bleed openings 39 between the rim and central portion of the impeller. Passage of fuel through the ports 38 is controlled by a valve 40 connected with the impeller and loaded by a valve closing spring 41.

The impeller, shaft, and cam provide means for exerting a force on the switch arm 20 in opposition to the force exerted on the latter by the bellows assembly of the air section; the magnitude of the counter force varying proportionately with the extent of movement or displacement of the impeller about its axis in response to flow conditions in the fluid of the impeller chamber.

The signal unit B, shown in Figures 4 and 7, comprises a lamp housing 42 divided into concentric inner and outer lamp chambers 43 and 44; the former having a red cover glass 45 bearing the legend "No flow" and the latter having a green cover glass 46 bearing the legend "Excessive flow." The central and smaller chamber 43 houses a single electric lamp 47. A pair of similar lamps 48 and 48*a* are housed within the outer and larger chamber 44. The lamp 47 has an electrical lead or conductor 49 connected through an electrical adapter socket 50 on the signal control unit A with a conductor 51 of the switch mechanism contact 52. Lamps 48 and 48*a* have a common conductor 53 similarly connected with a conductor 54 of the switch mechanism contact 55. As shown in Figure 2, contacts 52 and 55 are fixed in the body portion 2 in vertically spaced relation on relatively opposite sides of one end of the switch arm 20. The switch arm is pivotally supported at its other end on a post or pedestal 56 for movement vertically between the contacts and is provided with a conductor 57 and condenser 58 for connection through the adapter socket 50 and conductor 59 with the aircraft engine ignition circuit.

A typical fuel system with the above described fuel flow warning device installed therein is shown in Figure 4. The system, apart from the incorporation of the subject invention therein, comprises main and auxiliary fuel tanks 60 and 61 with fuel outlet tubes 60*a* and 61*a* to a selector valve 62. The fuel line from the selector valve to the engine-driven main fuel pump 63 and

hand-operated booster pump 64 is indicated at 65 and includes the strainer 66. The outlets of the pumps are connected through a common fuel delivery tube 67 to the carburetor fuel inlet 68. The carburetor 69 is shown provided with an air scoop or ramming air intake 70 and a throttle 71. A supercharger 72 is located in the induction system between the carburetor and the engine intake manifold 73. The conventional pump 63 is designed to deliver much more fuel at any speed than the engine actually requires, the surplus fuel being relieved to the intake side of the pump by the automatic action of a differential pressure operated relief valve of the well-known bellows or diaphragm type vented on one side to the fuel pressure and on the other side to the carburetor air intake pressure. The relief valve, shown conventionally at 74 with air vent line 75 to the carburetor impact tube 76, by its balancing action helps to maintain constant pump discharge pressure regardless of variations in pressure on the suction side of the pump. The conventional differential pressure gage for indicating the difference between the air pressure at the carburetor air inlet and the fuel pressure entering the carburetor is shown at 77 with its air connection 78 vented to the carburetor air intake through vent line 79 and impact tube 76, and its fuel connection 80 connected to the carburetor fuel inlet 68 by a fuel vent line 81.

The conventional fuel pressure warning signal comprises a red signal lamp 82 and the signal switch 83 in circuit connection with a source of potential 84 and a cut-out switch 85; the signal lamp being conveniently located in the pilot's compartment and the signal switch being installed close to the carburetor. The signal switch is a differential pressure operated type vented to fuel pressure on one side through the fuel connection 86 with the fuel vent line 81 and to carburetor air pressure on the other side through the air connection 87 with the air vent line 79. During normal engine operation the fuel pressure is sufficiently high to keep the signal switch 83 open so that the lamp 82 is unlighted. Upon a serious loss or drop in fuel pressure the signal switch closes and lights the lamp in warning to the pilot of low-fuel pressure. Since operation of the fuel pressure warning signal is required only during engine operation it is generally connected in the engine ignition circuit with the conventional storage battery as the source of potential 84 and the presently employed ignition switch as the cut-out switch 85.

In installing the fuel flow warning device in the conventional fuel system, the signal control unit A is located in the fuel line on the intake side of the fuel pump, preferably between the selector valve 62 and the strainer 66, with the switch arm conductor 59 connected as a branch lead with the ignition switch point 88. The signal unit B is mounted in the pilot's compartment on the instrument panel or otherwise conspicuously located in the vicinity of the pilot. Chamber 11 of the unit A is connected to the impact tube 76 through vent tubes 89 and 79 and registers the carburetor air intake or scoop pressure. Chamber 12 is connected by a vent tube 90 with the throat of a Venturi tube 91 in the direct air flow of the engine induction system and registers Venturi suction. In normal engine operation, the flow volume of fuel should be at a predetermined value corresponding to the mass air flow at the carburetor for each engine operating condition. The pressure difference between chambers 11 and 12 is a measure of mass air flow and, hence, a measure of the instant fuel consumption of the engine. This pressure difference acting on the bellows 10 produces a force acting downwardly through the spring 21 upon the switch arm 20. Movement of the fuel through the impeller chamber of the unit A in the normal direction of flow tends to displace the impeller clockwise about its axis for producing a force which is a measure of the fuel flow. This force is applied to the switch arm through the medium of the shaft 29 and cam 31 in opposition to the force produced by the pressure differential between chambers 11 and 12 and applied to the switch arm in the manner hereinbefore described.

The adjustment and calibration of the signal-control unit A is such that the impeller, switch arm, and associated parts are caused to assume different given positions according to whether the fuel flow is normal, subnormal, or abnormal. The normal position is represented by the dotted line construction P of Figures 5 and 6 and is assumed when the fuel system is operating normally, as when the fuel flow corresponds to the consumption requirements of the engine. In this condition of fuel system operation, the opposing forces on the switch arm 20 hold the latter centered between, and hence in open circuit position relative to, the contacts 52 and 55; the impeller 24 being in flow-sustained attitude substantially midway of the upper and lower limits of the travel with the valve 40 in unseated relation to the impeller fuel ports 38. The signal lamps 47, 48 and 48a are unlighted because of the break in circuit at the signal control unit switch.

The subnormal or "No flow" position is represented by the full line construction P_x of Figure 5 and is assumed when the flow of fuel ceases or drops below the required rate. Such a condition may be encountered, during engine operation, as a result of restriction or exhaustion of the fuel between the supply source and the fuel pump, failure in the carburetor, or irregular fuel flow. Figure 5 illustrates a condition of subnormal fuel flow due to the lack of adequate fuel supply. The fuel in the part of the system from the fuel tank to the fuel pump contains air and the flow is low and erratic, being pulsating rather than uniform; a common occurrence when the quantity of fuel in the fuel tank is insufficient to maintain uniform flow, particularly when the aircraft is operated in attitudes which prevent or retard fuel flow. Erratic fuel flow from the fuel tank to the inlet of the fuel pump most always is encountered prior to the exhaustion of the fuel system or malfunctioning of the high pressure side of system between the fuel pump and the carburetor. This condition of low and erratic fuel flow is not immediately reflected in the high pressure side of the fuel system because of the operating characteristics of the conventional fuel pump whereby normal operating fuel pressure is maintained in the discharge or high pressure side of the fuel system for a considerable period after the fuel flow in the low pressure side of the system has dropped to an unsafe value. Hence, during this period of malfunction the conventional fuel pressure gauge and the fuel drop warning device continue to indicate normal operating fuel pressure indicative of safe engine and fuel system operating conditions. With the fuel flow warning device of the present invention installed in the system as shown and described, it is ob-

vious that decreased fuel flow between the tank and the fuel pump will decrease the fuel flow pressure against the impeller 24 with resultant lessening of the upward force applied to the underside of the switch arm 20 through the medium of the impeller shaft 29 and cam 31. As a result of the unbalancing of the opposed forces, with the downward force predominating, the switch arm is forced downward into engagement with the electrical contact 52 with consequent closing of the circuit to the remotely located signal lamp 47 and illumination of the latter to render a "No flow" warning to the pilot. The downward movement of the switch arm results in a counter clockwise movement of the cam 31, shaft 29, and impeller 24 from the normal position P to the "No flow" position P_x. It should be noted that at this particular time the fuel pressure gauge 77 and the unlighted drop warning lamp 82 are recording a normal condition of fuel system operation. When the condition of decreased flow is remedied, as by switching the selector valve 62 to another fuel tank or taking other corrective action to restore the fuel flow to the required normal value, the switch mechanism is restored to position P and the "No flow" warning lamp is extinguished indicating resumption of normal operation of the fuel system.

The abnormal or "Excessive flow" position is represented by the full line construction P_y of Figure 6 and is assumed when the flow of fuel exceeds the required fuel consumption of the engine. Such a condition commonly occurs when leakage at a section or connection of the tubing on the pressure side of the fuel system results in loss of fuel to the external area, as indicated at *y* in Figure 6. The fuel loss to the carburetor is compensated by an increase in the fuel flow and fuel volume output of the fuel pump as long as the fuel supply is adequate; the capacity of the fuel pump 63 being much greater than the maximum engine consumption and is regulated by the relief valve 74 to maintain the correct fuel pressure value. Hence, during the occurrence of such a condition or malfunctioning of the system, the conventional fuel pressure guage and fuel drop warning device continue to indicate normal operating fuel pressure indicative of safe engine and fuel system operating conditions although actually a serious fire hazard is present. Timely warning of such a hazardous condition is afforded however, by the incorporation into the fuel system of the warning device of the subject invention which is responsive to variations in fuel flow rather than variations in fuel pressure. Acceleration in fuel flow resulting from increased pump action due to malfunctioning of the system increases the upward pressure or force exerted against the underside of switch arm 20 through the medium of the impeller shafts 29 and 31. As a result of the unbalancing of the opposed forces, with the upward force predominating, a clockwise movement of the impeller 24 shaft 29 and cam 31 occurs until the "Excessive flow" position P_y is reached, at which time the switch arm engages the electrical contact 55 and closes the circuit to the lamps 48 and 48*a* with consequent illumination of the lamps to render a warning of "Excessive flow" to the pilot. When, by corrective action with resultant decrease in fuel flow, the proper balance between the opposed forces is restored in conformity with the fuel consumption requirements of the engine, as measured or guaged by the pressure difference between the chambers 11 and 12, the switch mechanism is activated to normal position P and the "Excessive flow" lamps are extinguished in indication of normal operation of the fuel system.

The fuel flow warning device, being responsive to fuel flow conditions, will render signal indications substantially immediately upon the occurrence of a fuel flow which is disproportionate to requirements of the system for normal engine operation. Hence, it affords a correction period of greater duration prior to engine failure than is afforded by the conventional fuel pressure gauge 77 and fuel drop warning signal 82 which are responsive to variations in fuel pressure rather than fuel flow. As previously pointed out herein, such undesirable flow conditions may exist for some time without drop in fuel pressure and, therefore without indication thereof either by the fuel pressure guage or the fuel drop warning signal. The fuel flow warning device is not intended to eliminate the fuel pressure guage or the fuel pressure drop warning signal but to provide a supplementary warning device contributing to greater safety in aircraft engine operation. It can be readily adapted to pressure types of fuel systems for aircraft without major alterations to the fuel system and is designed to be constructionally and operationally fool proof and free from malfunctioning within the limits of possibility. The switch mechanism operates under a negative pressure afforded by Venturi suction which eliminates possibilities of moisture condensation and electrical arcing. The free and valve-controlled fuel ports in the impeller assure proper fuel flow should the impeller become jammed or stuck in the flow passage from any condition of malfunctioning. A double pole, test switch S, shown in Figure 4, may be connected in the fuel flow switch signal circuits for testing purposes, if desired.

Although the fuel flow warning device is herein shown and described as affording immediate warning signal to the pilot through means of an electrical circuit and lamps, the same objective may be attained by the use of an auditory signal. It is to be understood, therefore, that alterations and changes in the construction of the device, and the substitution of equivalents, may be made without departing from the spirit and scope of the inventions as set forth in the appended claims.

Having thus described the invention, we claim:

1. A fuel flow warning device for an engine fuel feed system, comprising opposed pressure responsive means one of which is connected in the high pressure side of the system to be operated thereby for exerting a force proportional to the instant fuel consumption of the engine and the other of which is in communication with the low pressure side of the system to be operated thereby for exerting a force proportional to the fuel flow, and a signalling circuit including a switch operatively connected with the said opposed force exerting means to be maintained thereby in circuit-open position when the opposed forces are in balanced relationship and to be moved into circuit-closed position when the opposed forces are in unbalanced relationship.

2. In a fuel system, a carburetor, a fuel source, a fuel feed line connecting the fuel source with the carburetor and including a fuel feed pump, opposed force-exerting means one of which is operatively connected with the carburetor to exert a force which is a function of the air flow through the carburetor and the other of which is operatively connected to the fuel line between the pump and the fuel source to exert a force which is a function of the fuel flow between the pump and

the fuel source, and a signal circuit having a circuit-control switch operatively connected with the said opposed force-exerting means to be maintained in circuit-open position when the opposed forces are equal and to be moved to close the circuit when the said forces are unbalanced.

3. A fluid pressure actuated switch comprising a housing having a fluid pressure chamber and a fluid-flow passage, said chamber having a fluid-pressure inlet, a pivotally mounted switch arm in the pressure chamber, contact points in the path of the switch arm and on relatively opposite side of the latter, a pressure-sensitive bellows within the chamber and having a pressure inlet externally of the chamber for the transmission of pressure to the interior of the bellows, a force-transmitting spring connecting the bellows and the switch arm, a shaft journaled in the housing and extending crosswise of the flow passage, an impeller fixedly connected with the shaft and depending into the flow passage, and a cam fixed on the shaft and engaging the switch arm in opposition to the said spring.

4. A fuel flow warning system having in combination a fuel consuming device, means for feeding fuel to the device, force-exerting means connected with the device and operable thereby in accordance with the rate of fuel consumed by the device for producing a variable force which is proportional to the rate of fuel consumption and which is a measure of the required rate of fuel flow to the device, force exerting means connected with the fuel feeding means and operable thereby in accordance with the rate of fuel flow therethrough for producing a variable force proportional to the rate of fuel flow, the two force-exerting means being in relatively opposed relation for effecting a resultant force which corresponds to the instantaneous relation of the fuel flow through the fuel feeding means and the fuel consumed by the device, and means responsive to the said resultant force for visibly and continuously indicating said instantaneous relation.

5. In an engine fuel feed system, the combination of a source of fuel supply, an engine induction housing, a fuel pump having an intake connection with the fuel supply source and a delivery connection with the induction housing, opposed force-exerting means; one of which is a pressure-sensitive element vented to induction housing impact pressure on one side and to induction housing velocity pressure on the other side to exert a force proportional to the engine consumption and the other of which is a flow responsive member operatively connected with the intake side of the pump and operable to exert a force proportional to the fuel flow on one side of the pump, and a signalling circuit including a control switch connected to and operated by the said opposed force-exerting means to be maintained in circuit-open position when the opposed forces are in equilibrium and to be moved into circuit-closed position whenever said forces are in unbalanced relationship.

6. In a fuel system, a carburetor, a fuel source, a fuel feed pump connected between the carburetor and the fuel source, a pair of electrical signalling circuits including a common control switch movable from an open circuit position in one direction to close one of the circuits and in the opposite direction to close the companion circuit, and opposed force-exerting pressure-responsive means connected with the switch and operable when equal to hold the switch in circuit-open position, one of said means being responsive to the pressure difference between Venturi suction and impact pressure resulting from air flow through the carburetor to exert a force proportional to said airflow and tending to move the switch to close one of the circuits and the other means being responsive to fuel flow on the intake side of the pump to exert a force proportional to the fuel flow between the pump and the fuel source and tending to move the switch to close the other circuit whereby an unbalance between the opposed forces results in the closing of a signal circuit.

7. A fuel feed system including a carburetor having an air flow passage provided with a Venturi suction region and an impact pressure region, a fuel source, a fuel pump having an intake connection with the fuel source and a delivery connection with the carburetor, opposed pressure-responsive means one of which is vented to the carburetor Venturi suction on one side and to the carburetor impact pressure on the other side for exerting a force proportional to the pressure differential between the carburetor suction and impact pressure and the other of which is in communication with the intake side of the pump for exerting a force proportional to the fuel flow between the pump and the fuel source, and fuel flow indicating means including a movable member operatively connected between the opposed force-exerting means to be maintained in a given position when the opposed forces are equal and to be deflected to positions at relatively opposite sides of the given position when there is an unbalanced relationship between the said forces.

8. An engine fuel feed system including a carburetor, a fuel source, a fuel feed line connecting the fuel source with the carburetor and including a fuel feed pump, opposed force-exerting means one of said means being a differential pressure-responsive member connected with the carburetor and responsive to the pressure differential between the carburetor suction and impact pressures resulting from air flow through the carburetor to exert a force which is a measure of the instant fuel consumption of the engine and the other of said means being a pressure-responsive member connected to the fuel line between the pump and the fuel source and responsive to the fuel flow therein for exerting a force which is a measure of the fuel flow to the pump, and fuel flow indicator means including a movable member operatively connected with the opposed force exerting means to be maintained when the opposed forces are equal in a given position indicative of a normal fuel flow and to be deflected to positions at relatively opposite sides of the given position in accordance with an unbalanced relationship between the forces resulting from supernormal or subnormal fuel flow.

9. In an engine fuel system, an induction housing having a Venturi air passage and an air impact pressure tube, a fuel source, a fuel pump having its intake connected with the fuel source and its outlet connected with the housing, a suction chamber connected with the Venturi passage, a pressure chamber connected with the impact tube, a pressure-sensitive force-exerting device vented to the suction chamber on one side and to the pressure chamber on the other side for exerting a force proportional to the pressure differential between the suction and impact pressures, a flow-responsive force-exerting device operatively associated with the intake side of the pump for exerting a force proportional to the fuel flow from the fuel source to the pump, and a pair

of electrical signaling circuits including a common control switch movable from a circuit open position in one direction to close one circuit and in the opposite direction to close the other circuit, said switch being operatively associated with the said forces-exerting devices to be acted on oppositely by said devices whereby it will be positioned in circuit open position when the opposed forces are equal and moved to close one or the other of the circuits in accordance with an unbalance between the opposed forces.

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