

Oct. 5, 1948.

L. LEE, 2D

2,450,835

INDICATING APPARATUS.

Filed March 16, 1946

4 Sheets--Sheet 1

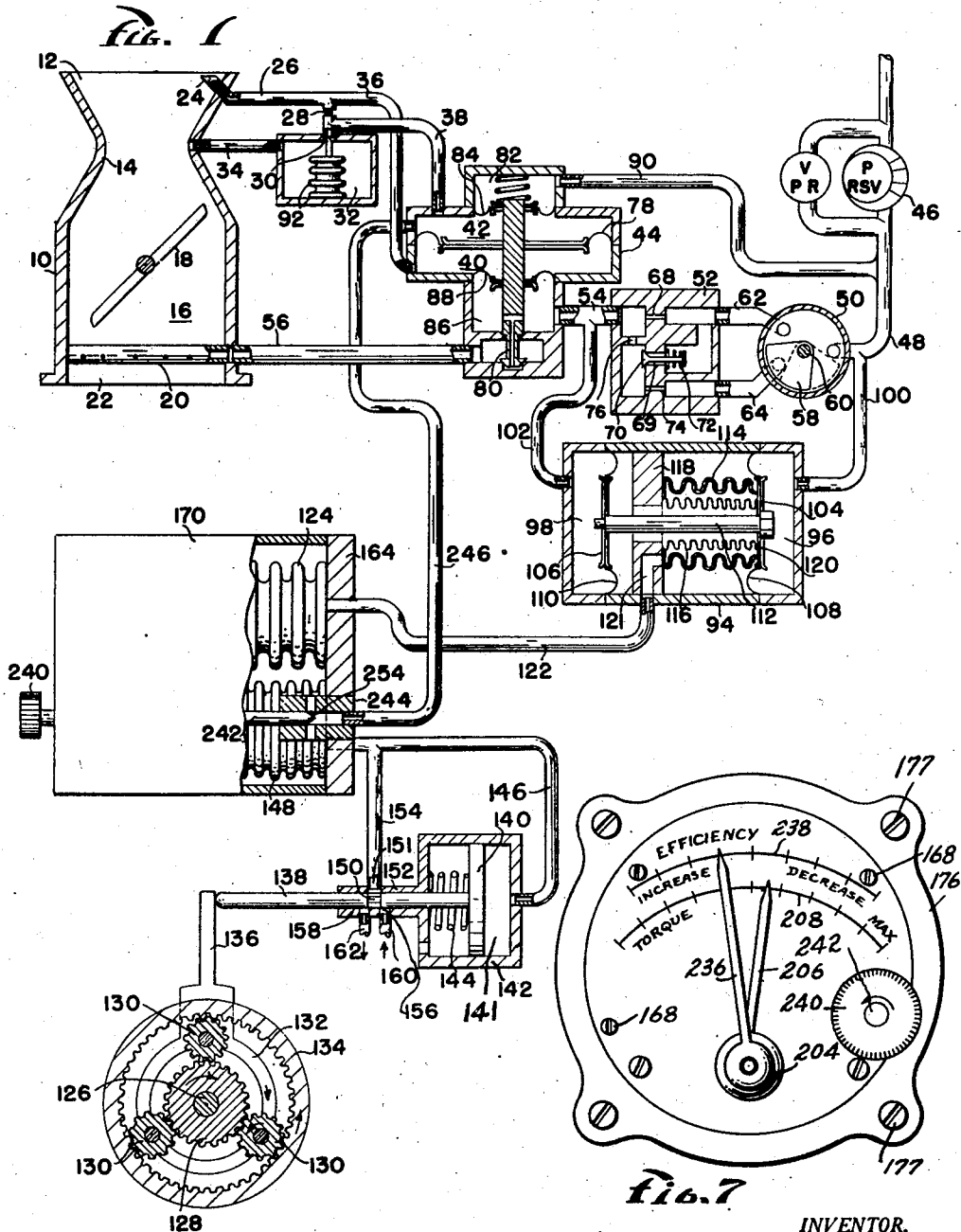


fig. 7

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Fig. 2

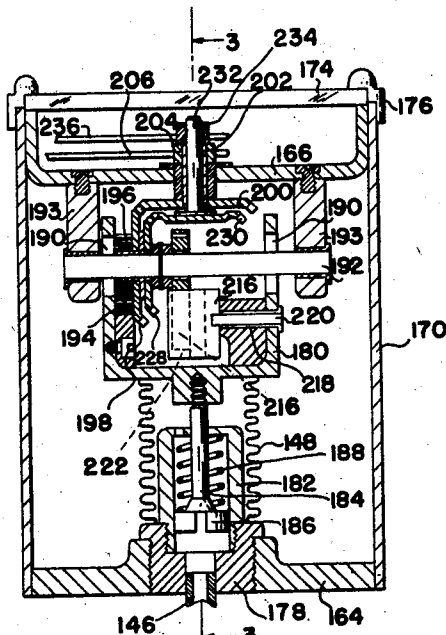
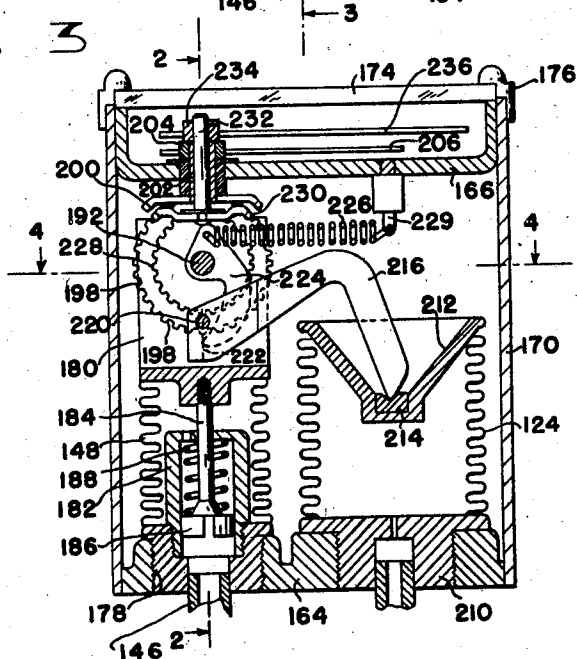


Fig. 3



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FIG. 4

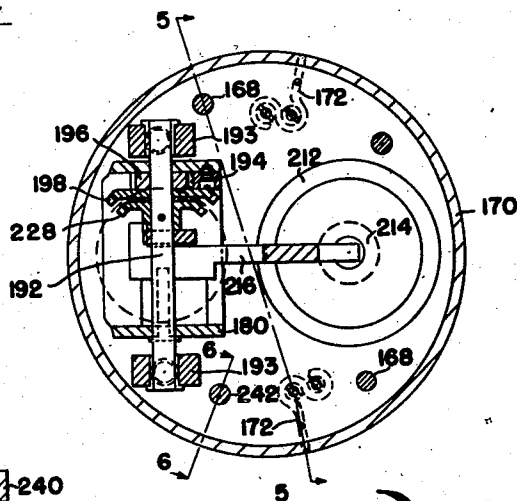


FIG. 6

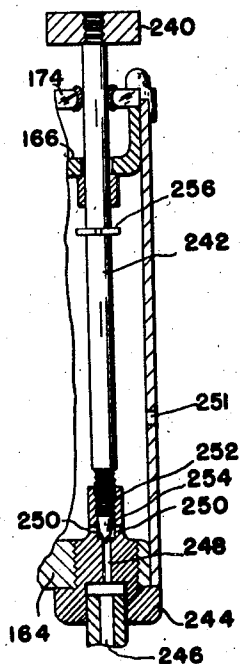
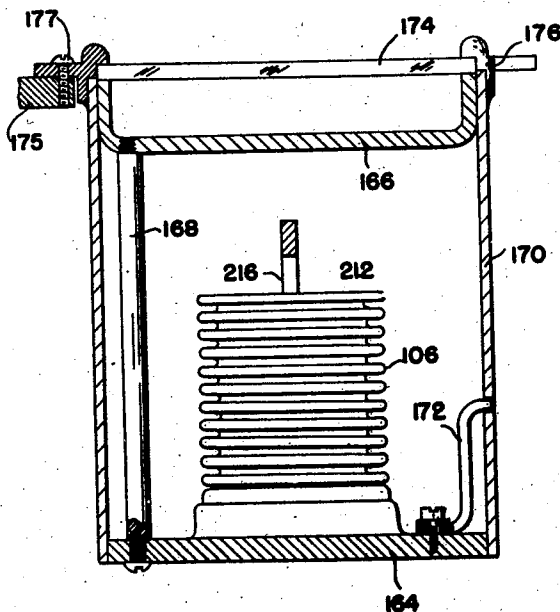


FIG. 5



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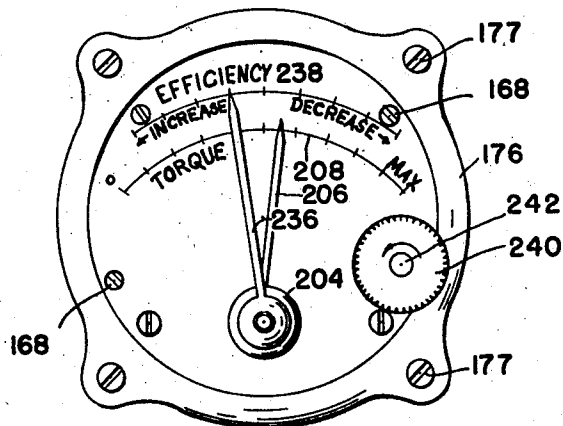
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4 Sheets-Sheet 4

Fig. 7



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INDICATING APPARATUS

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Application March 16, 1946, Serial No. 654,979

28 Claims. (Cl. 123—119)

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The invention relates more particularly to an internal combustion engine fuel supply system adapted for use in or as a part of an airplane, but the invention is not necessarily so limited.

One of the objects of the invention is to provide means which will enable the operator to readily adjust the fuel system for maximum efficiency of engine operation.

A further object of the invention is to provide means whereby the reading of the needle or other device which indicates efficiency will not be affected by variations in fuel flow corresponding to variations in the torque exerted by the engine.

A still further object of the invention is to provide an improved means responsive to the rate of fuel flow to the engine, such means being utilized for indicating the maximum efficiency.

Still other objects of the invention are to provide various improved details of structure and arrangement that are useful or advantageous in attaining the before-stated more general objects.

Further objects of the invention will be apparent from the accompanying drawings and from the following specification and claims.

Of the drawings:

Fig. 1 is a schematic view showing the essential elements associated with and forming parts of the efficiency indicator.

Fig. 2 is a longitudinal sectional view of the indicator unit, this view being taken along the line 2—2 of Fig. 3.

Fig. 3 is a longitudinal sectional view taken along the line 3—3 of Fig. 2.

Fig. 4 is a transverse sectional view taken along the line 4—4 of Fig. 3.

Fig. 5 is a longitudinal sectional view taken along the line 5—5 of Fig. 4.

Fig. 6 is an enlarged fragmentary sectional view taken along the line 6—6 of Fig. 4.

Fig. 7 is a plan view of the indicator unit.

While not necessarily so limited, the invention is particularly applicable to and advantageous for airplane use and it will be so described. Referring first to Fig. 1 of the drawings, there is shown a body 10 of a carburetor for an aircraft type internal combustion engine. Air enters the carburetor body 10 at an inlet 12 and flows through a Venturi restriction 14 and a passage 16, past a throttle 18 and a fuel discharge nozzle 20 to an outlet 22. A supercharger may be provided between the outlet 22 and the intake manifold of the engine. In certain cases the supercharger may be upstream from the inlet 12, or

two superchargers may be used, one in each place.

The Venturi restriction 14 produces a pressure differential between the inlet 12 and the throat of the restriction which varies substantially in accordance with the square of the velocity of the air passing through the restriction. Since the cross-sectional area of the venturi is constant, this pressure differential may be taken as a measure of the volume of air flowing through the passage per unit time. In order to obtain a pressure differential varying as a function of the mass of air per unit time flowing through the venturi 14, the pressure differential between the entrance 12 and the throat of venturi 14 is utilized to create an air flow through a secondary air passage extending from entrance 12 to the throat of venturi 14. A plurality of impact tubes 24 is provided, only one of which is shown, whose open ends project into the entrance 12 to receive the impact of the entering air. The secondary air passage may be traced from entrance 12, through tubes 24, a conduit 26, a conduit having a restriction at 28, a restriction controlled by a valve 30, a chamber 32 and a conduit 34 extending to the throat of the venturi 14. The conduits 26 and 28 are connected respectively with conduits 36 and 38 which communicate with chambers 40 and 42 in a pressure meter indicated generally at 44.

The fuel enters the carburetor from a fuel pump 46 or other source of fuel under superatmospheric pressure. It flows through a conduit 48 to a mixture control unit generally indicated at 50 and a jet system 52, and then through a conduit 54, the pressure meter 44 and a conduit 56 to the fuel discharge nozzle 20. The conduit 48, the mixture control unit 50, the jet system 52 and the conduit 54 will be referred to collectively as the "main fuel conduit."

The mixture control unit 50 includes a disc valve 58 fixed on a shaft 60. The disc valve 58 controls the flow of fuel through ports opening into conduits 62 and 64 which lead into the jet system 52. When the disc 58 is in the position illustrated in full lines in the drawing, fuel can flow to the jet system only through the conduit 62. This full line position of the disc valve 58 is known as the "lean" position of the mixture control 50. When the disc valve 58 is in the dotted line position shown in the drawing, the fuel can flow through both the conduits 62 and 64. The dotted line position of disc valve 58 is termed the "rich" position of the mixture control. The disc valve 58 can also be moved to a "cut-off"

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position wherein it cuts off the flow through both conduits 62 and 64.

The conduit 62 conducts fuel either through a fixed restriction or jet 68, or through a restriction 69 controlled by an enrichment valve 70 biased to closed position by a spring 72. The conduit 64 conducts fuel to a fixed restriction 74. Fuel flowing through the restrictions 68 and 74 also flows through another restriction 76 which limits the total flow through restrictions 68 and 74. The valve 70 is normally closed, but opens at high pressure differentials across the jet system to increase the fuel-to-air ratio under heavy load conditions.

The pressure meter 44 has a diaphragm 78 separating the chambers 40 and 42, this diaphragm being connected with a valve 80. The meter 44 also has a chamber 82 separated from the chamber 42 by a diaphragm 84, and a chamber 86 separated from the chamber 40 by a diaphragm 88. The diaphragms 84 and 88 are also operably connected with the valve 80. The chamber 86 receives fuel from the aforesaid conduit 54, and the downstream side of the valve 80 is connected with the aforesaid conduit 56 leading to the nozzle 20. The chamber 82 is connected by a conduit 90 with the conduit 48 at the upstream side of the jet system 52.

The pressure in the chamber 82 is the same as that in the fuel line at the upstream side of the jet system, and the pressure in the chamber 86 is the same as that in the fuel line at the downstream side of the jet system. The position of valve 80 is determined by the balance between the differential of the pressures in the chambers 40 and 42 acting in the valve opening direction and the differential of the pressures in the chambers 82 and 86 acting in the valve closing direction. Increased air flow results in increased differential between the pressures in the chambers 40 and 42 and causes the valve 80 to move in the opening direction to increase the fuel flow and thus maintain the proper air-to-fuel ratio. However, the increased fuel flow causes an increased differential of pressures across the jet system and in the chambers 82 and 86 which tends to move the valve 80 in the closing direction and to establish a new balance between the two differentials.

The before-mentioned valve 30 in the secondary air passage constitutes a second restriction therein, the first restriction being at 28. It will be clear that closing or partial closing of this valve increases the pressure drop at that point, and correspondingly decreases the pressure drop at the restriction 28. Decrease of the pressure drop at 28 decreases the pressure differential on the diaphragm 78 and tends to move the valve 80 in the closing direction, and to thus decrease the fuel flow in the manner already described. Similarly, movement of the valve 30 in the opening direction increases the fuel flow. The valve 30 therefore serves as a means for regulating the fuel flow supplementally to the regulation effected by variations in air velocity. The valve 30 is connected with a bellows 92 positioned in the chamber 32 and filled with a fluid having a substantial coefficient of thermal expansion. Increased temperature or decreased pressure in the chamber 32 causes the bellows to expand and move the valve 30 in the closing direction, thus decreasing the rate of fuel supply. Decreased temperature or increased pressure in the chamber 32 causes the bellows to collapse and move the valve 30 in the opening direction, thus increasing the rate of fuel supply.

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In accordance with the invention it is necessary to provide means for indicating the rate of flow of fuel to the engine and a means for this purpose having certain important advantages is shown in Fig. 1. An enclosure 94 is provided having two chambers 96 and 98 at opposite ends thereof. These chambers are connected with the main fuel conduit respectively at opposite sides of the jet system by means of conduits 100 and 102. The inner walls of said chambers are formed by flexible diaphragms 108 and 110, whose central portions are clamped between pairs of rigid discs 104 and 106. The two diaphragms 108 and 110 are connected for movement in unison by means of a central rod 112. Inasmuch as the said movable walls are rigidly connected with each other they are adapted to exert a force toward the left which is a function of the differential between the pressures in the two chambers, and inasmuch as the two chambers are connected at opposite sides of the jet system the pressure differential represents the drop in pressure across the jet system, which drop in pressure, for a given jet area, is a function of the rate of fuel flow through the main fuel conduit. In order that the before-described pressure differential may be utilized, a suitable pressure transmitting device is employed, and as shown, this device comprises two concentric flexible bellows 114 and 116 which are carried by a partition 118 in the enclosure 94. The bellows are closed at their outer right ends by a movable wall 120 which is adjacent the movable wall 104. The space between the two bellows is entirely closed except for a duct 121 in the partition 118, the said duct being connected with a conduit 122. The conduit 122 leads to a suitable pressure responsive means such as a bellows 124 forming a part of an indicator unit shown more fully in other figures of the drawings and hereinafter described in detail. The space between the two bellows 114 and 116, the duct 121, the conduit 122, and the bellows 124 is filled with a liquid having a low coefficient of thermal expansion.

From the foregoing description it will be seen that the pressures in the chambers 96 and 98 are the same respectively as the pressures in the main fuel conduit at the upstream side of the jet system and at the downstream side of the jet system. The drop in pressure across the jet system is proportionate to the rate of fuel flow, and therefore the pressure differential between the two chambers 96 and 98 is also proportionate to the rate of fuel flow. Inasmuch as the two walls or discs 104 and 106 are rigidly connected by the rod 112 the result is that the force applied to the end wall 120 of the two bellows 114 and 116 is proportionate to the said pressure differential and therefore proportionate to the rate of fuel flow. This pressure is transmitted to the bellows 124 and tends to expand it. The space between the diaphragms 108 and 110 which is not occupied by the bellows 114 and 116 is filled with air or other suitable fluid and is sealed. While this gives a small unbalanced force on the end of bellows 114 due to the pressure of the sealed-in fluid, this pressure is constant and hence does not disturb the calibration of the system.

In accordance with the invention it is also necessary to provide means movable in accordance with the torque delivered by the internal combustion engine with which the apparatus is being used. As shown in the lower part of Fig. 1, the shaft 126 is the crank shaft of the engine or is directly connected to the crank shaft. The shaft

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126 carries a gear 128 which meshes with a plurality of pinions 130, 130 carried by a substantially stationary spider 132. The pinions 130, 130 also mesh with an internal gear 134 which is connected with the airplane propeller or other device being driven by the engine. This gearing mechanism is part of the usual reduction gearing used between the engine and the propeller on modern aircraft.

The spider 132, while substantially stationary, is nevertheless rotatable within narrow limits. It carries an outward projecting arm 136 which abuts against a longitudinally movable rod 138. The rod 138 carries a piston 140 movable in and closely fitting a cylinder 142. A spring 144 within the cylinder tends to move the piston toward the right. Connected with the right end of the cylinder 142 is a conduit 146 connected with a suitable pressure responsive means such as a bellows 148 forming a part of the indicating unit before referred to. The space in the cylinder 142 at the right of the piston, the conduit 146, and the bellows 148 are filled with a suitable liquid.

The torque delivered by the shaft 126 to the ring gear 134 is transmitted thru the spider 132 and this torque tends not only to rotate the ring gear in the counter-clockwise direction, but also to rotate the spider 132 in the clockwise direction. The arm 136 carried by spider 132 applies a force to the rod 138 and to the piston 140 which is proportionate to the amount of the torque. The rod 138 is provided with an annular groove 150 which normally registers with a port 151 formed in a sleeve 152 attached to the cylinder 142, this port communicating with a conduit 154 which is connected with the beforementioned conduit 146. Also formed in the hub 152 are two ports 156 and 158 which are spaced apart by a distance the same as or slightly greater than the width of the groove 150 and which are therefore out of register with the groove when the latter is aligned with port 151. The port 156 at the right is connected with a conduit 160 leading from a source of liquid under pressure and the port 158 at the left is connected with a drain conduit 162. With the parts in the positions shown in Fig. 1 the ports 156 and 158 are closed. As long as the force due to the torque, which acts to the right on rod 138 and piston 140, is balanced by the fluid pressure acting to the left on piston 140, then the rod 138 remains in the position shown. If the torque increases, however, or if by reason of leakage of liquid past the piston 140, the piston and the rod move toward the right, the port 156 will be uncovered, thus permitting liquid under pressure to flow from the conduit 160 through the conduit 154 and thence through the conduit 146 into the right end of the cylinder so as to move the piston and the rod toward the left at least sufficiently to close the port 156. If the movement of rod 138 to the right was due to leakage, the liquid so admitted will be just sufficient to restore the previously existing pressure in chamber 141 and bellows 148. If the movement was due to a change in torque, then the liquid will be admitted until the pressure in chamber 141 is sufficient to balance the increased force. This increased pressure is transmitted to bellows 148, causing expansion thereof to indicate the increased torque. If the piston should be moved toward the left in response to a decrease in torque, the port 158 will be opened, thus permitting some of the liquid to pass through the drain conduit 162 and permitting the piston to return to its normal position. This decreases the pressure in bel-

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lows 148 and causes contraction thereof to indicate the decreased torque.

The indicating unit is shown in Figs. 2 to 7 and will now be described in detail. It comprises a circular base 164 and an upwardly flanged top wall 166. The members 164 and 166 are connected by a plurality of upright posts 168, one of which is shown in Fig. 5. Surrounding the members 164 and 166 is a peripheral side wall 170 in which the assembly attached to base 164 is removably held by two spring clips 172, 172. The spring clips 172, 172 are connected by screws to the base 164 and their upper ends project into apertures in the side wall 170. When the assembly is put in place the spring clips snap into the apertures in the side wall, but the assembly can be removed by manually pushing the spring clips inward. Resting on the upward extending annular flange of the top wall 166 is a glass cover 174 which is held in place on a panel 175, which may be part of the dashboard of an aircraft, by a ring 176 connected with the panel 175 by means of screws 177, 177.

The bellows 148 which is responsive to the torque exerted by the engine is carried by a plug 178 fitting an aperture in the base 164. For visually indicating the torque of the engine there is provided an indicator or needle 206 operable by the bellows 148. This needle can be variously operated and one suitable means for this purpose will now be described.

The upper end of the bellows 148 is closed by a movable yoke 180 which is U-shaped in cross section as shown in Fig. 2. Carried by the plug 178 is a cylinder 182 with an apertured top wall through which extends a rod 184. The rod 184 has threaded engagement at its upper end with the yoke 180 and at its lower end is provided with a head 186 which is guided for vertical movement in the cylinder. A compression coil spring 188 within the cylinder 182 abuts at the top against the top wall of the cylinder and at the bottom against the head 186. The head 186 has a deep slot which provides communication to the interior of the cylinder from the conduit 146 and the top wall of the cylinder is provided with an aperture which provides communication with the interior of the bellows. It will be seen that fluid pressure within the bellows tends to move the yoke 180 upward but that this upward movement is opposed by the coil spring 188. The movement of the yoke is proportionate to the amount of the torque exerted by the engine.

The two upstanding legs of the yoke 180 are provided with vertical slots 190, 190 through which extends a horizontal shaft 192. The shaft 192 is rotatable in bearings carried by brackets 193, 193 depending from the top plate 166. It will be seen that the shaft 192 by reason of its engagement with the walls of the slots in the yoke serves to guide the yoke for vertical movement and to limit its vertical movement within certain predetermined limits. The left leg of the yoke 180, as viewed in Fig. 2, carries a vertical rack 194 which meshes with a pinion 196 rotatably mounted on the shaft 192. Connected with the pinion 196 and rotatable therewith is a bevel gear 198. The bevel gear 198 meshes with a bevel gear 200 which is carried by a rotatable sleeve 202 extending upward through the top wall 166. At the upper end of the sleeve 202 is a hub 204 carrying indicator needle 206 which is positioned between the wall 166 and the glass cover 174. The needle 206 is adapted to cooperate with an arcuate scale 208 on the top face of the wall 166, and

it will be seen that the readings of the needle 206 on the scale 208 represent the amount of the torque exerted by the engine.

The beforementioned bellows 124, which is responsive to the rate of fuel flow, is carried by a plug 210 in an aperture in the base 164 and pressure is transmitted to the interior of the bellows from the conduit 122 through an aperture in the said plug.

A second indicator or needle is provided which is operated or controlled in part by the bellows 124. This second needle is also controlled in part by the torque responsive bellows 148, so that the needle visually indicates efficiency of the engine, instead of indicating the total rate of fuel flow. The construction is such that the needle indicates only so much of any increases or decreases in fuel flow as are not directly proportionate to increases or decreases in torque. The means for operating or controlling the abovementioned second needle will now be described.

The bellows 124 is closed at the top by a member 212 having a deep conical recess therein, a bearing element 214 being provided at the bottom of the said conical recess. An arm 216 engages at one end with the bearing element 214 and is pivotally connected with the yoke 180 for movement about a horizontal axis. The right hand leg of the yoke 180, as shown in Fig. 2, carries a bearing bushing 218 within which is mounted a pivot pin 220 which is fixedly connected with the said arm 216. The vertical position of pin 220 varies with the torque, since it is positioned by bellows 48. The arm 216 has a surface 222, shown in dotted lines in Fig. 3, which is normally vertical or substantially so, and which extends approximately through the axis of the pivot pin 220. Mounted on the shaft 192 is a lever 224, the lower end of which is in contact with the beforementioned surface 222 on the arm 216. The vertical position of the lower end of lever 224 is substantially constant. Therefore, the vertical distance between pin 220 and the lower end of lever 224 is a measure of the torque developed by the engine. The range of movement of the surface 222 with respect to the engaging point on the lever 224 is determined by the length of the slots 190, 190. The construction is such that the lever 224 always engages the surface 222 below the pivotal axis at 220.

A coil tension spring 226 is connected with the upper end of lever 224 and with a stud 229 projecting downward from the top wall 166. This spring tends to rotate the lever 224 in the clockwise direction, and thereby holds the lower end of lever 224 in engagement with the surface 222. The lever 224 is fixed on the shaft 192 for rotation therewith.

Shaft 192 carries a bevel gear 228 meshing with a bevel gear 230 carried by a vertical shaft 232. The shaft 232 is mounted within the bushing 202 and carries at its upper end a hub 234 with a needle or pointer 236 thereon. The needle 236 is positioned in the space between the wall 166 and the top cover 174 and is above the needle 206. The top wall 166 is provided with a scale 238 with which the needle cooperates. The pointer 236 is biased by spring 226 to its full-scale position. As explained in detail below, the reading of the needle 236 with respect to the scale 238 indicates the efficiency of the engine.

The pressure in bellows 124, which, as previously described, is a measure of the rate of fuel flow to the engine, produces a force acting upwardly on the end of arm 216, which is likewise a meas-

ure of the rate of fuel flow. This force provides a torque which tends to rotate arm 216 counter-clockwise. For any given stable set of conditions, this torque is opposed by an equal and opposite clockwise torque acting through the lower end of lever 224 on surface 222. The moment arm of this clockwise torque about the pivot 220 is proportional to the torque developed by the engine, as previously explained. Therefore, it may be stated that the force producing this clockwise torque about pivot 220 must be proportional to the fuel flow to the engine and inversely proportional to the torque developed by the engine. However, this force is proportional to the deflection of the spring 226 from its normal position and hence to the deflection of pointer 236 from its full-scale reading. It therefore follows that the deflection of pointer 236 from its full-scale position is proportional to the fuel flow to the engine and inversely proportional to the torque. In other words, the deflection of the pointer 236 from its zero position is an indication of the torque developed per unit fuel flow. If the engine speed is held constant, as is usually the case in modern aircraft engines, which are equipped with governors which vary the propeller pitch to hold the engine speed constant, then the torque developed per unit fuel flow is a measure of the useful power developed per unit fuel flow, or of the efficiency of the engine.

Means is provided, preferably as a part of the indicator unit, whereby the operator can readily adjust the fuel-air ratio in order to attain maximum efficiency, as indicated by the needle 236 on the scale 238. For this purpose there is provided a knob 240 on a shaft 242 which extends downward through the glass cover 174 and the top wall 166 into engagement with a valve plug 244 in an aperture in the base 164. These parts are shown most clearly in Fig. 6. Connected with the valve plug 244 is conduit 246 which communicates at its other end with the chamber 42 in the pressure meter 44. The valve plug 244 has a central aperture 248 with lateral apertures 250, 250 communicating with the interior of the indicator unit, which is vented to the atmosphere as indicated at 251. The shaft 242 is threaded into the end of the plug 244, as indicated at 252, and is provided with a needle valve 254 adjacent the apertures 250, 250. A suitable device on the shaft 242 prevents the shaft from being unscrewed sufficiently to entirely disengage the threads at 252, and this may be a split washer 256 entering an annular groove in the shaft. The knob 240 is removable so that the inner assembly may be removed from casing 170. The valve 254 is initially in position to entirely close the apertures 250, 250 but subsequently the valve 254 can be withdrawn sufficiently to open the apertures 250, 250 to whatever extent may be required.

The engine efficiency indicator to which this invention more particularly relates is ordinarily not used until after take-off and until after the airplane has reached the cruising altitude which has been decided upon. Then the propeller and the throttle are adjusted to provide the rate of propeller rotation and the cruising speed that are deemed desirable. Under these conditions the needle 206, controlled and operated in the manner already described, will indicate the amount of torque being exerted by the motor, which will be assumed to have an intermediate value as indicated in Fig. 7. The mixture control unit 50 will ordinarily be in the lean position with the

fuel flowing to the jet system through the conduit 82.

With the airplane operating as described, it may be assumed that the rate of fuel flow is greater than that representing maximum efficiency. The pilot or the flight engineer will then reduce the fuel-air ratio to attain maximum efficiency. This is done by turning the knob 240 to slightly open the valve 254 and permit air to flow inward through the apertures 250, 250, the aperture 248 and the conduit 246, to the high suction or low pressure chamber 42 of the pressure meter 44. Air entering the apertures 250, 250 from the interior of the indicating unit is replaced by air entering the said unit through the apertures in which are entered the detents 172, 172, or through the vent 251. The entry of air into the chamber 42 increases the pressure in the said chamber and reduces the pressure differential tending to move the valve 80 in the opening direction. This permits the valve 80 to move in the closing direction thus reducing the flow of fuel to the nozzle 20. If the reduction in the rate of fuel flow increases the efficiency, then the pointer 236 moves to the left along scale 238, and the pilot continues to open the valve 254 until the needle 236 gives a maximum reading on the scale 238, this maximum reading representing maximum efficiency.

The reduction in the rate of fuel flow not only increases the efficiency but it may also reduce the torque exerted by the engine, as indicated by the reading of the needle 206 on the scale 208. However, the construction that has been described is such that the movement of the needle 236 with respect to the scale 238 indicates only so much of the reduction in the rate of fuel flow as represents increased efficiency, and there is no change in reading resulting from that part of the reduction in fuel flow corresponding to reduced torque.

Any reduction in torque causes the yoke 180 to move downward carrying with it the pivot pin 220. As the axis of the pivot pin 220 moves downward the moment arm of the force applied by the spring 226 through the lever 224 to the arm 216 is correspondingly reduced. This reduction in moment arm causes a reduction in the clockwise torque applied to the arm 216 which reduction is proportionate to the decreased torque. This reduced clockwise torque counterbalances so much of the reduction in the counter-clockwise torque produced by the bellows 124 as results from decreased fuel flow corresponding to decreased torque. The net result is that any movement of the needle 236 toward the right directly indicates decreased efficiency, and does not represent any reduction in fuel flow corresponding to decreased torque.

Since the efficiency meter described does not take into account the engine speed nor the position of the mixture control 50, the position of needle 236 does not indicate efficiency in terms of power output per unit fuel flow or any other fixed units. However, for a given position of the mixture control and for a given engine speed, both of which remain fixed for long periods on modern aircraft, the position of needle 236 relative to scale 238 is a measure of the efficiency of the engine. When, under such conditions, the knob 240 is adjusted to make needle 236 move as far as possible to the left, the engine is operating at its maximum possible efficiency.

After the described adjustment in the rate of fuel flow has been made by means of the knob 240, so as to provide maximum efficiency as indi-

cated by the needle 236, the throttle may be opened to restore the torque to its original value and when this is done the carburetor acts automatically to maintain the same or substantially the same ratio of fuel flow to air flow. The pressure in the bellows 124 is increased proportionately to the increased fuel flow but the increased torque gives the spring 226 an increased mechanical advantage with the result that an increased clockwise torque is applied to arm 216 which counterbalances the increased counter-clockwise torque due to the increase of pressure in bellows 124. The needle 236 will not move because of the increased torque, except as the increased torque may involve an incidental change in efficiency. After the restoration of the torque to its original value the operator should again check the efficiency by adjusting the knob 240 to make sure that the reading of the efficiency indicator needle 236 is at a maximum position indicating maximum efficiency.

If operating conditions from time to time require increases or decreases in torque, such increases or decreases do not affect the reading of the needle 236 except as such increases or decreases may result in changes in efficiency. After each major change in torque the knob 240 should be adjusted to make sure that the engine is operating at maximum efficiency.

It will be clear that any reduction in the rate of fuel flow effected by means of the knob 240 must be governed by observation of the needle 236 and discontinued when the needle shows maximum efficiency. Too great a reduction in the rate of fuel would result in too lean a mixture and in decreased efficiency which would cause the needle 236 to shift toward the right from its maximum efficiency position.

It has been stated that the mixture control valve will ordinarily be in its lean position when reductions in the rate of fuel flow are made by means of the knob 240. By reason of the location of the mixture control valve in the lean position, it may sometimes be found that the mixture is already too lean and that any further leaning of the mixture by means of the knob 240 results in decreased efficiency rather than increased efficiency. This would instantly be observed by the operator, as he would find that the leaning of the mixture by means of the knob 240 would cause the needle 236 to move toward the right instead of toward the left thus indicating a decrease in efficiency rather than an increase. In this event the operator should shift the mixture control valve to its rich position, and then operate the knob 240 to lean the mixture to whatever extent might be necessary to attain maximum efficiency.

While I have shown and described a certain preferred embodiment of my invention, other embodiments thereof will readily occur to those skilled in the art, and I therefore intend my invention to be limited only by the appended claims.

I claim as my invention:

1. In an efficiency indicator for an internal combustion engine, the combination of means for indicating the maximum efficiency of the engine in terms of torque developed per unit of fuel flow to the engine, and means for preventing variations in the action of the first said means resulting from changes in engine torque.

2. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the torque of the engine and independent of engine speed, means responsive to

the rate of flow of fuel to the engine, and a movable needle controlled by both of the said means.

3. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the rate of flow of fuel to the engine, a needle operably connected with the said fuel flow responsive means, and means responsive to the torque of the engine and independent of engine speed for modifying the operative relationship between the said needle and the said fuel flow responsive means.

4. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the torque of the engine and independent of engine speed, means responsive to the rate of flow of fuel to the engine, a needle operably connected with the fuel flow responsive means, and mechanism controlled by the torque responsive means for varying the extent of movement of the needle inversely with variations in the torque.

5. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the torque of the engine and independent of engine speed, means responsive to the rate of flow of fuel to the engine, a movable needle operatively connected with the fuel flow responsive means, and mechanism controlled by the torque responsive means for resisting the movement of the fuel flow responsive means to an extent inversely proportionate to the torque.

6. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the rate of flow of fuel to the engine, a needle operatively connected with the said fuel flow responsive means, a spring opposing the action of the fuel flow responsive means, and means responsive to the torque of the engine for changing the mechanical advantage of the spring in accordance with changes in torque.

7. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the rate of flow of fuel to the engine, a needle operably connected with the said fuel flow responsive means, a spring opposing the action of the fuel flow responsive means, and means responsive to the torque of the engine for increasing the mechanical advantage of the spring in accordance with increases in torque and for decreasing the mechanical advantage of the spring in accordance with decreases in torque.

8. In an efficiency indicator for an internal combustion engine, the combination of means responsive to the rate of flow of fuel to the engine, a needle operably connected with the said fuel flow responsive means, a spring opposing the action of the fuel flow responsive means, and means responsive to the torque of the engine for changing the mechanical advantage of the spring in inverse proportion to changes in torque.

9. A fuel system for an internal combustion engine comprising in combination, means for indicating the maximum efficiency of the engine, means for preventing variations in the action of the first said means resulting from changes in engine torque, and manually operable means for adjusting the rate of fuel flow to effect maximum efficiency as indicated by the first said means.

10. A fuel system for an internal combustion engine comprising in combination, means responsive to the torque of the engine, means responsive to the rate of flow of fuel to the engine,

a needle operably connected with the fuel flow responsive means, mechanism controlled by the torque responsive means for varying the extent of movement of the needle inversely with variations in the torque, and manually operable means for adjusting the rate of fuel flow to effect maximum efficiency as indicated by the said needle.

11. A fuel system for an internal combustion engine comprising in combination, means responsive to the rate of flow of fuel to the engine, a needle operatively connected with the said fuel flow responsive means, a spring opposing the action of the fuel flow responsive means, means responsive to the torque of the engine for changing the mechanical advantage of the spring in inverse proportion to changes in torque, and manually operable means for adjusting the rate of fuel flow to effect maximum efficiency as indicated by the said needle.

12. A fuel system for an internal combustion engine, comprising in combination, a passage including a venturi for air flowing to the engine for combustion purposes, a pressure meter having two chambers and a flexible diaphragm separating the chambers, conduits connecting the Venturi entrance and throat with the respective chambers, a valve operable by the diaphragm and controlling the flow of fuel to the engine, the said valve being moved in the opening direction by an increase in the pressure differential between the two chambers and being moved in the closing direction by a decrease in the said differential, means responsive to the torque of the engine, means responsive to the rate of flow of fuel to the engine, a needle operably connected with the fuel flow responsive means, mechanism controlled by the torque responsive means for varying the extent of movement of the needle inversely in accordance with variations in torque, and manually operable means for decreasing the pressure differential between the two chambers to move the valve in the closing direction and thus reduce the rate of fuel flow to effect maximum efficiency as indicated by the said needle.

13. A fuel system for an internal combustion engine, comprising in combination, a passage including a venturi for air flowing to the engine for combustion purposes, a pressure meter having two chambers and a flexible diaphragm separating the chambers, conduits connecting the Venturi entrance and the throat thereof with the respective chambers, a valve operable by the diaphragm and controlling the flow of fuel to the engine, the said valve being moved in the opening direction by an increase in the pressure differential between the two chambers and being moved in the closing direction by a decrease in the said differential, means responsive to the torque of the engine, means responsive to the rate of flow of fuel to the engine, a needle operably connected with the fuel flow responsive means, mechanism controlled by the torque responsive means for varying the extent of movement of the needle inversely in accordance with variations in torque, and manually operable means for admitting air to the chamber having the lower pressure to decrease the pressure differential between the two chambers to move the valve in the closing direction and thus reduce the rate of fuel flow to effect maximum efficiency as indicated by the said needle.

14. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means movable in response to pressure representing the torque exerted by the engine, an indicator

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needle movable by the said means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a second needle operably connected with the fuel flow responsive means, and mechanism operable in part by the torque responsive means for varying the movements of the second needle inversely in accordance with variations in torque.

15. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means responsive to pressure representing the torque exerted by the engine, a needle operable by the torque responsive means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a needle operably connected with the fuel flow responsive means, and mechanism controlled by the torque responsive means for varying the extent of movement of the second said needle.

16. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means responsive to pressure representing the torque exerted by the engine, a needle operable by the torque responsive means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a needle operably connected with the fuel flow responsive means, and mechanism controlled by the torque responsive means for varying the extent of movement of the second said needle inversely in accordance with variations in torque.

17. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means responsive to pressure representing the torque exerted by the engine, a pivoted needle operable by the said means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a needle operably connected with the fuel flow responsive means and pivoted coaxially with the first said needle, and mechanism controlled by the torque responsive means for varying the extent of movement of the second said needle.

18. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means responsive to pressure representing the torque exerted by the engine, a needle operable by the torque responsive means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a needle operably connected with the fuel flow responsive means, and mechanism controlled by the torque responsive means for resisting the movement of the fuel flow responsive means to an extent varying inversely with the torque.

19. An efficiency indicator unit for an internal combustion engine, comprising in combination, a yoke movable in response to pressure representing the torque exerted by the engine, a pivoted needle, gearing connecting the needle with the yoke for operating the former in accordance with movement of the latter to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a second pivoted needle, gearing for operating the second needle, and mechanism connecting the fuel flow responsive means with the second gearing to operate the second said needle, the said mechanism being carried in part by the yoke whereby movement of the yoke varies the operation of the second said needle.

20. An efficiency indicator unit for an internal combustion engine, comprising in combination, a yoke movable in response to pressure representing the torque exerted by the engine, a pivoted needle,

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gearing connecting the needle with the yoke for operating the former in accordance with movement of the latter to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a second pivoted needle, gearing connected with the fuel flow responsive means for operating the second needle, an arm pivoted to the movable yoke and engaging the fuel flow responsive means to oppose the movement thereof, and a spring actuated lever pivoted for rotation about a fixed axis and engaging the said arm to rotate it in the opposing direction, the engagement of the said lever with the said arm being at varying distances from the movable axis of the latter so that the arm exerts varying pressures on the fuel flow responsive means.

21. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means movable in response to pressure representing the torque exerted by the engine, an indicator needle movable by the said means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a second needle operably connected with the fuel flow responsive means, mechanism operable in part by the torque responsive means for varying the movements of the second needle inversely in accordance with variations in torque, and manually operable means for adjusting the rate of fuel flow to effect maximum efficiency as indicated by the second said needle.

22. An efficiency indicator unit for an internal combustion engine, comprising in combination, a means responsive to pressure representing the torque exerted by the engine, a needle operable by the torque responsive means to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a needle operably connected with the fuel flow responsive means, mechanism controlled by the torque responsive means for varying the extent of movement of the second said needle, and manually operable means for adjusting the rate of fuel flow to effect maximum efficiency as indicated by the second said needle.

23. An efficiency indicator unit for an internal combustion engine, comprising in combination, a yoke movable in response to pressure representing the torque exerted by the engine, a pivoted needle, gearing connecting the needle with the yoke for operating the former in accordance with movement of the latter to indicate the amount of torque, a means responsive to pressure representing the rate of fuel flow to the engine, a second pivoted needle, gearing for operating the second needle, mechanism connecting the fuel flow responsive means with the second gearing to operate the second said needle, the said mechanism being carried in part by the yoke whereby movement of the yoke varies the operation of the second said needle, and manually operable means for adjusting the rate of fuel flow to effect maximum efficiency as indicated by the second said needle.

24. In a fuel supply system for an internal combustion engine, the combination of a main fuel conduit including a jet means, two chambers connected with the main fuel conduit at the respective sides of the jet means, movable means associated with the said chambers so that pressure in one chamber tends to move it in one direction and pressure in the other chamber tends to move it in the opposite direction, the

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said means being therefore movable in response to the differential between the pressures in the two chambers, and means for transmitting the pressure exerted by the said movable means.

25. In a fuel supply system for an internal combustion engine, the combination of a main fuel conduit including a jet means, two chambers connected with the main fuel conduit at the respective sides of the jet means, movable means associated with the said chambers so that pressure in one chamber tends to move it in one direction and pressure in the other chamber tends to move it in the opposite direction, the said means being therefore movable in response to the differential between the pressures in the two chambers, a bellows positioned to be moved in the collapsing direction by movement of the said movable means, and a conduit connected with the interior of the bellows and adapted to transmit fluid pressure to a pressure responsive means.

26. In a fuel supply system for an internal combustion engine, the combination of a main fuel conduit including a jet means, two chambers connected with the main fuel conduit at the respective sides of the jet means, each chamber having a movable wall and the two walls being so positioned that the pressures in the respective chambers tend to move them in opposite directions, means for connecting the two movable walls for movement in unison in response to the differential between the pressures in the two chambers, and means for transmitting the pressure exerted by the said connected movable walls.

27. In a fuel supply system for an internal combustion engine, the combination of a main fuel conduit including a jet means, two chambers connected with the main fuel conduit at the respective sides of the jet means, each chamber having a movable wall and the two walls being so positioned that the pressures in the

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respective chambers tend to move them in opposite directions, means for connecting the two movable walls for movement in unison in response to the differential between the pressures in the two chambers, a bellows positioned between the two movable walls and movable by one of them in the collapsing direction, and a conduit connected with the interior of the bellows and adapted to transmit fluid pressure to a pressure responsive means.

28. Apparatus for indicating the ratio between a first variable and a second variable, comprising a first lever fixed to a shaft, means biasing said shaft for rotation in a predetermined sense, a second lever engaging said first lever at a predetermined point thereon spaced from said shaft, means responsive to said first variable for applying a torque to said second lever so as to transmit a force to said first lever in a sense to oppose said biasing means, a pivot for said second lever, means responsive to said second variable for shifting said pivot so as to vary the moment arm of said torque inversely as said second variable, and means for indicating the rotation of said shaft.

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