

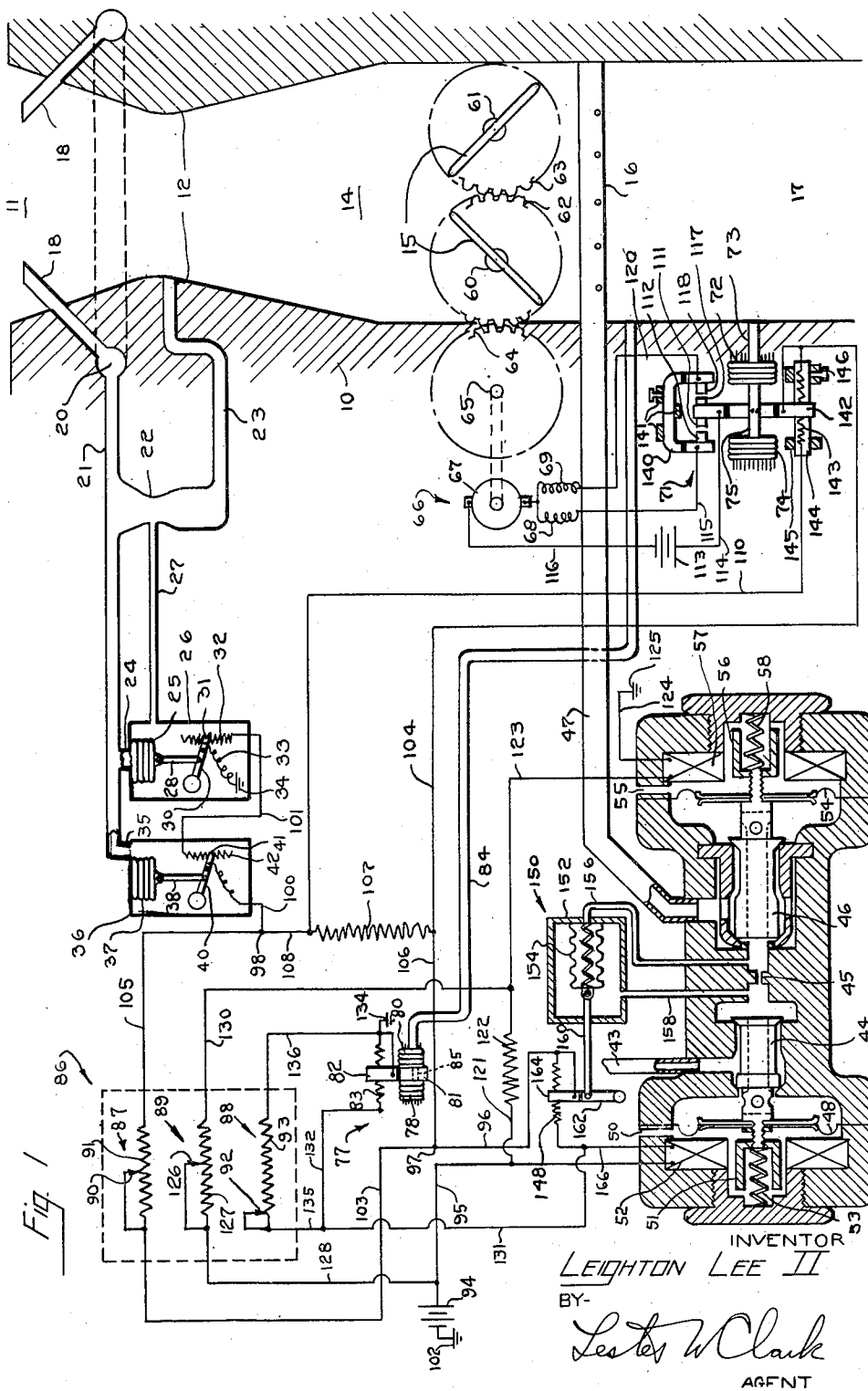
Jan. 3, 1950

L. LEE, II
CARBURETOR

2,493,587

Filed Sept. 28, 1943

3 Sheets-Sheet 1



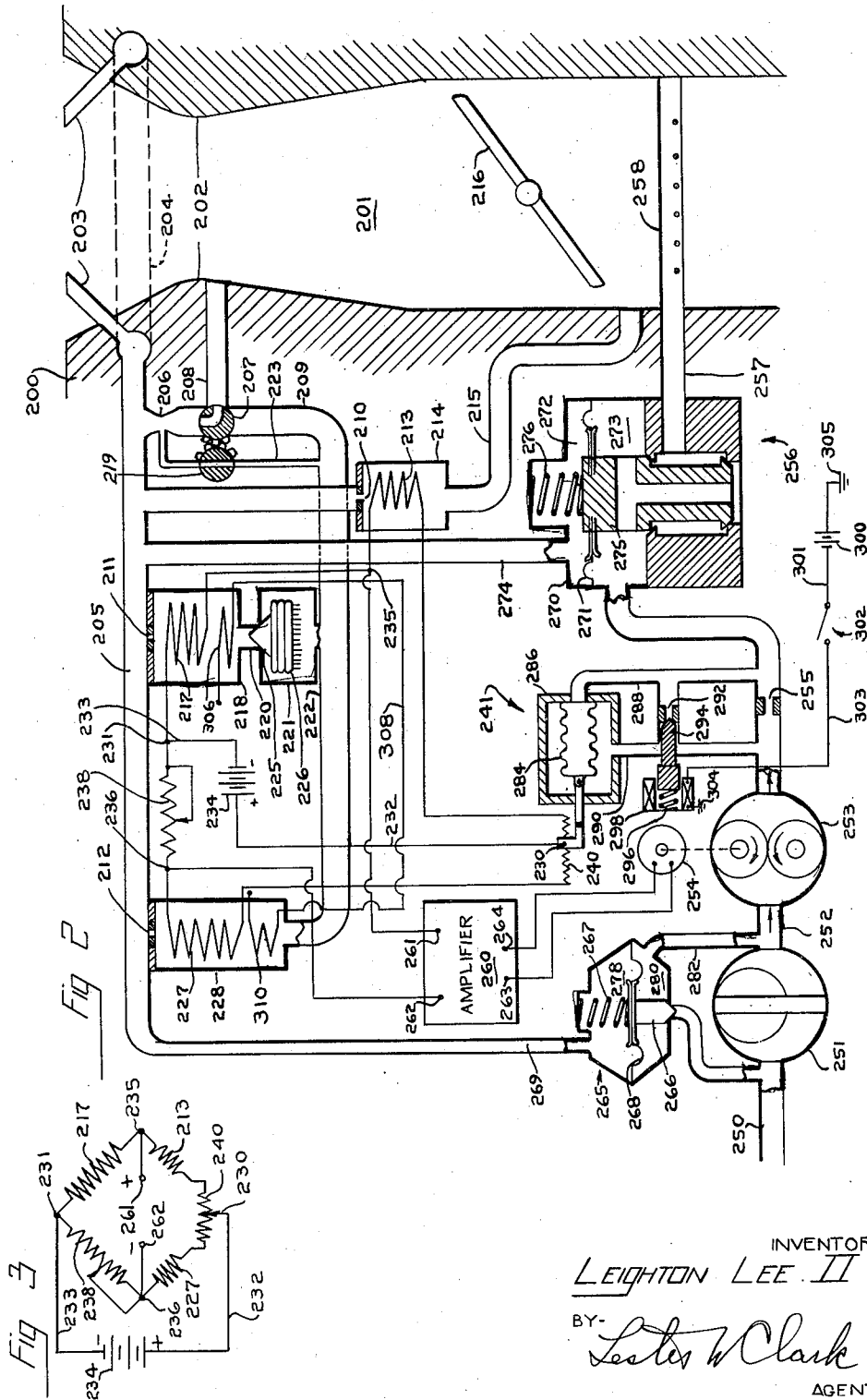
Jan. 3, 1950

L. LEE, II
CARBURETOR

2,493,587

Filed Sept. 28, 1943

3 Sheets-Sheet 2



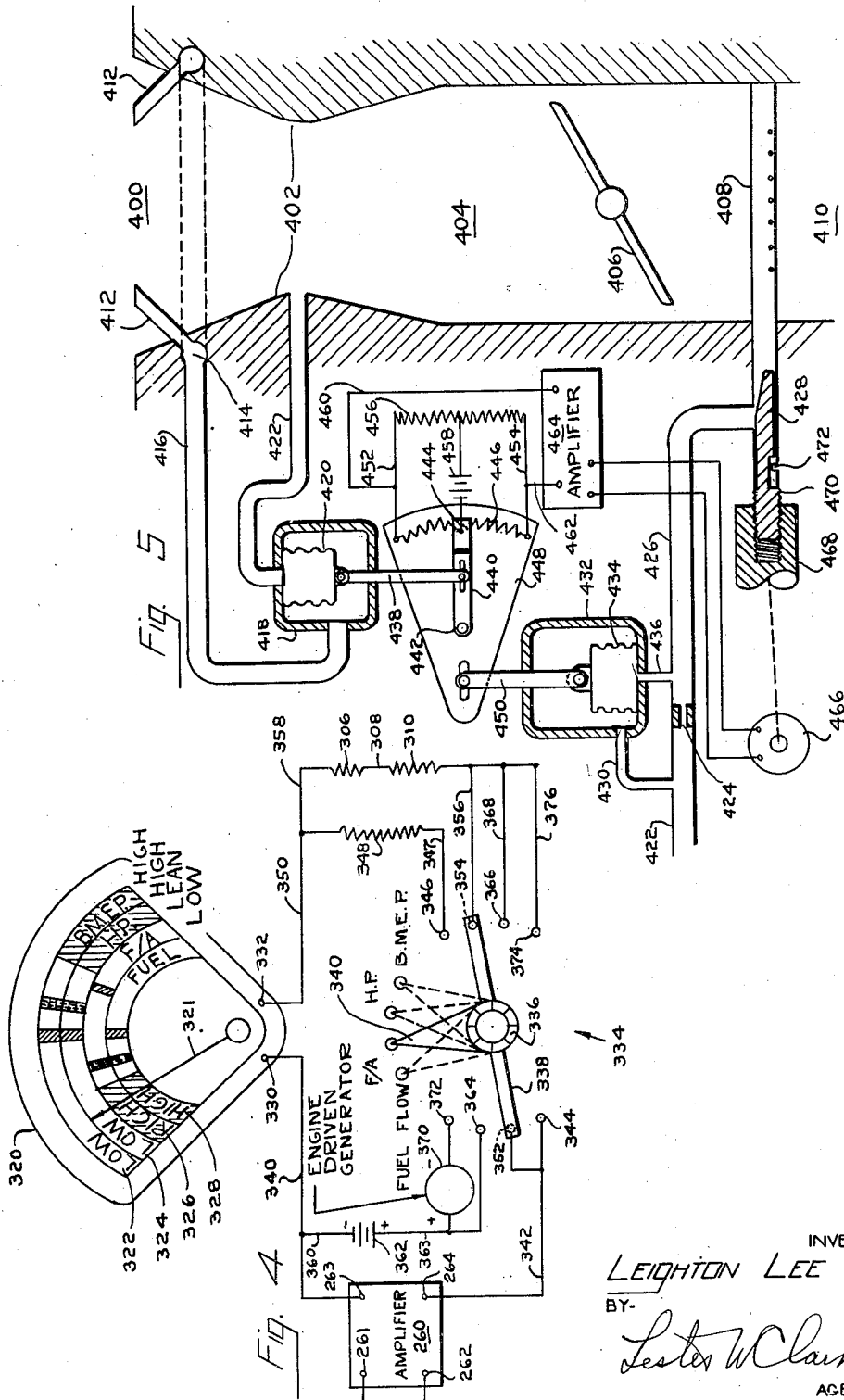
Jan. 3, 1950

L. LEE, II
CARBURETOR

2,493,587

Filed Sept. 28, 1943

3 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,493,587

CARBURETOR

Leighton Lee, II, Meriden, Conn., assignor, by
mesne assignments, to Niles-Bement-Pond
Company, West Hartford, Conn., a corporation
of New Jersey

Application September 28, 1943, Serial No. 504,098

31 Claims. (Cl. 123—119)

1

The present invention relates to carburetors and particularly to carburetors of the type in which the quantity of fuel supplied to the engine is proportioned with respect to the quantity of air supplied.

It is an object of this invention to provide improved means for controlling the quantity of fuel supplied to an internal combustion engine as a function of the quantity of air supplied to support combustion of that fuel.

Another object of the invention is to provide an arrangement wherein the quantity of fuel supplied to an internal combustion engine is electrically controlled. A still further object is to provide an electrically operated carburetor in which the fuel flow is controlled in accordance with the resultant of a number of variable conditions, such as air flow, air density, and intake manifold pressure.

Another object is to provide an electrical carburetor in which the quantity of fuel flowing to the engine is not affected by variations in the voltage of the source of electrical energy.

Another object is to provide improved electrical flow controlling means for a carburetor, including means responsive to the acceleration of the engine on which the carburetor is mounted for enriching the fuel and air mixture upon such acceleration.

A further object of the present invention is to provide electrical means for controlling the flow of fuel to an internal combustion engine, wherein means is provided so that upon failure of the electrical power supply, the engine receives a quantity of fuel sufficient to operate it at a predetermined proportion of its rated output.

A further object of the present invention is to provide improved means for indicating various operating conditions of an internal combustion engine, such as fuel flow, fuel to air ratio, horse power output, and brake mean effective pressure.

Other objects and advantages of the present invention will become apparent from a consideration of the appended specification, claims and drawings, in which

Figure 1 is a somewhat diagrammatic illustration of a carburetor with an electrical control system embodying the principles of my invention,

Figure 2 illustrates a carburetor provided with a modified form of electrical control system,

Figure 3 is an electrical wiring diagram of a control circuit shown in Figure 2,

Figure 4 is a somewhat diagrammatic illustration of an electrical system for indicating

2

various engine conditions which may be used with the carburetor of Figure 2, and

Figure 5 is a somewhat diagrammatic illustration of another form of electrical control system for a carburetor.

Referring now to Figure 1, there is shown a carburetor body 10, thru which air flows from an inlet 11 past a Venturi restriction 12, and thru a passage 14 past throttles 15 and a discharge nozzle 16 to an outlet 17.

A portion of the air entering the inlet 11 enters impact tubes 18 whose open ends extend into the path of that air, and from these impact tubes flows thru a second passage which terminates at the throat of venturi 12. This second air passage may be traced from the impact tubes 18 thru a vent ring 20 which interconnects the tubes 18, a conduit 21, a boost venturi 22 and a conduit 23 to the throat of the main venturi 12.

The conduit 21 is connected thru a conduit 24 to the interior of a flexible bellows 25 mounted inside a casing 26. The interior of casing 26 is connected thru a conduit 27 to the throat of boost venturi 22.

In accordance with the known principles of fluid flow, the pressure differential between the impact tubes 18 and the throat of venturi 12 is a measure of the velocity of air entering the engine thru the carburetor 10. The boost venturi 22 is provided to amplify this pressure differential. The bellows 25 is exposed to the amplified pressure differential, and therefore expands and contracts in accordance with the changes in the velocity of air flowing thru the carburetor. The free end of bellows 25 is connected thru a link 28 to a pivoted arm 30, which insulatingly carries at its free end a slider 31 which cooperates with a slidewire resistance 32. This slider 31 is connected thru a pig tail connection 33 to a ground connection 34. The position of the sliding contact 31 along resistance 32 is determined by the differential pressure acting on the bellows 25, and hence by the velocity of air flowing thru the carburetor.

Conduit 21 is also connected thru a conduit 35 to the interior of a casing 36 in which a sealed bellows 37 is mounted. The bellows 37 is connected thru a link 38 to an arm 40 which is pivotally mounted at one end, and carries at its free end a sliding contact 41 which cooperates with a slidewire resistance 42. The position of contact 41 along resistance 42 is determined by the absolute pressure in the casing 36, since the bellows 37 is sealed. The slider 41 is therefore positioned in accordance with the variations in

the absolute pressure in the inlet 11, which pressure is transmitted to the interior of the casing 36 thru vent ring 18 and conduits 21 and 35. The bellows 37 may be filled with nitrogen or other suitable temperature responsive fluid, in order that the position of contact 41 may also reflect temperature changes.

The fuel entering the carburetor comes from a pump or other source of fuel under pressure (not shown) and flows thru a conduit 43, past a valve 44, a metering restriction 45, another valve 46, and a conduit 47 to the discharge nozzle 16. The metering restriction 45 is intended as a more or less diagrammatic representation of a jet system which may include a number of individual restrictions, either fixed or variable.

The valve 44, which is balanced against inlet pressure, is carried by a flexible diaphragm 48, one side of which is exposed to the pressure of the fuel on the outlet side of valve 44, and the opposite side of which is vented at 50. This vent may be to the atmosphere, as indicated in the drawing, or more preferably to the vent ring 20. The diaphragm 48 also carries an armature 51, which cooperates with an electromagnetic coil 52. A spring 53 biases the diaphragm 48 for movement to the right, in the opening direction of valve 44. The armature 51 has its magnetic center to the left of center of coil 52, so that energization of that coil tends to cause movement of armature 51 to the right, thereby applying an additional opening force to the valve 44, and causing an increase in the pressure at the inlet side of the restriction 45.

The valve 46, which is balanced against outlet pressure, is carried by a flexible diaphragm 54, one side of which is subjected to the pressure on the inlet side of valve 46 and whose opposite side is vented at 55. As in the case of vent 50, the vent 55 may be connected either to atmosphere or to vent ring 20. However, the vents 50 and 55 should be connected to the same source of pressure. The diaphragm 54 also carries an armature 56 which cooperates with an electromagnetic coil 57. A compression spring 58 biases the diaphragm 54 for movement to the left, in the closing direction of valve 46. The magnetic center of armature 56 is to the right of the center of coil 57, so that upon energization of coil 57, an additional closing force is exerted on valve 56, causing the fuel pressure to rise on the discharge side of the restriction 45.

The throttles 15 are carried by shafts 60 and 61, on which are fixed mating gears 62 and 63, respectively. The gears 62 and 63 are driven thru another gear 64 which meshes with gear 62, and is fixed on a shaft 65 driven thru a reduction gear (not shown) by an electrical motor generally indicated at 66. The motor 66 is illustrated as being of the series wound type, and is provided with an armature 67 and a pair of field windings 68 and 69. The energization of motor 66 is controlled by a switch mechanism generally indicated at 71. The switch mechanism 71 is operated in accordance with the balance between an evacuated bellows 74 and a bellows 72 whose interior is connected thru a conduit 73 to the mixture outlet 17 of the carburetor. The conduit 73 may alternatively be connected to the engine intake manifold.

The bellows 72 expands and contracts in accordance with the difference between the pressure in the mixture outlet 17, which acts on its interior, and atmospheric pressure, which acts on its exterior. The bellows 74, which is evacuated,

expands and contracts in accordance with atmospheric pressure only. The free ends of the bellows 72 and 74 are connected by a rod 75 which insulatingly carries a pair of contacts 111 and 117. The contacts 111 and 117 cooperate respectively with stationary contacts 112 and 118, which are mounted on a yoke member 140. The yoke member 140 is adjustable in guides 141, one of which is provided with a set screw for fixing the yoke member 140 in any adjusted position. Since the effects of variations in atmospheric pressure on the bellows 72 and 74 act in opposition to each other, as far as the position of rod 75 is concerned, it may be seen that rod 75 is positioned in accordance with the absolute pressure in the mixture outlet 17.

The rod 75 also carries a sliding contact 142, which cooperates with a slidewire resistance 143, for a purpose to be described hereinafter. The resistance 143 is mounted on a base 144 adjustable in a set of guides 145. One of the guides is provided with a set screw 140 for locking the base 144 in any adjusted position.

An acceleration control unit 77 includes a pair of flexible bellows 78 and 80. The free ends of the bellows 78 and 80 support an arm 81 which insulatingly carries a sliding contact 82 cooperating with a slidewire resistance element 83. The interior of bellows 80 is connected thru a conduit 84 to the mixture outlet 17 downstream from the throttles 15. The interiors of bellows 78 and 80 are connected by a restricted passage 85 of less capacity than the conduit 84. The construction is such that upon an increase in pressure at the mixture outlet 17, such as accompanies an opening of the throttles, the bellows 80 expands more rapidly than the bellows 78, due to the restricted communication between the bellows, thereby moving the arm 81 and contact 82 to the left. Since contact 82 is connected to the right end of resistance 83, the resistance between the terminals of 83 is thereby decreased. The resistance of element 83 is therefore decreased upon acceleration. Likewise, the resistance of element 83 is increased upon deceleration.

A manual control unit generally indicated at 86 includes a mixture control 87, a priming control 88 and a cut off control 89. The mixture control 87 includes a contact 90 movable along a slidewire resistance 91. The priming control 88 includes a contact 92 movable along a slidewire resistance 93. The cut-off control 89 includes a contact 126 movable along a slidewire resistance 127.

A resistance element 148 is varied by a control device 150 in accordance with the quantity of fuel flowing thru the restriction 45, as measured by the pressure drop across that restriction. The device 150 includes a casing 152 enclosing a flexible bellows 154. The interior of bellows 154 is connected thru a conduit 156 to the fuel supply line at a point downstream from the restriction 45, while the exterior of bellows 154 is exposed to the pressure in the interior of casing 152, which is connected thru a conduit 158 to the fuel supply line at a point upstream from the restriction 45. The expansion and contraction of bellows 154 therefore depends upon the pressure differential across the restriction 45. The free end of bellows 154, whose position depends upon the expansion and contraction of the bellows, is attached to a link 160, whose opposite end is attached to a pivoted arm 162, which insulatingly carries at its end a contact 164 cooperating with resistance 148. Contact 164 is

connected to the right end of resistance 148. An increase in the pressure differential across restriction 45 causes a contraction of the bellows 154 and a consequent movement of arm 162 to the right, thereby increasing the proportion of the total resistance of element 148 which is effective in the circuit connected to its terminals.

Operation of Figure 1

The energization of coil 52 which operates the valve 44 of Figure 1 is controlled by two electrical circuits, of which one, hereinafter termed the main energizing circuit, may be traced from the right hand terminal of a battery 94 thru a conductor 95, coil 52, a conductor 166, resistance 148, a conductor 96 to a junction 97, thence thru three parallel branches to a junction 98, and thence thru a conductor 100, contact 41, resistance 42, a conductor 101, resistance 32, contact 31, conductor 33 and ground connections 34 and 102 to the left terminal of battery 94. One of the three branches between junctions 97 and 98 may be traced from junction 97 thru a conductor 103, resistance 91 and a conductor 105 to junction 98. A second of these three branches may be traced from junction 97 thru a conductor 106, a fixed resistance 107 and a conductor 108 to junction 98. The third of these three branches may be traced from junction 97 thru conductors 106 and 104, sliding contact 142, resistance 143, and conductors 110 and 108 to junction 98.

As previously described, an increase in the energization of coil 52 causes an opening movement of valve 44 and hence an increase in the pressure of the fuel on the inlet side of the restriction 45 and a consequent increase in the quantity of fuel supplied to the engine. In the main energizing circuit for coil 52, there are five variable resistances which control the current flow thru that circuit in accordance with five variable conditions. These five resistance elements are the resistance 32 which is varied in accordance with the quantity of air entering the carburetor, the resistance 42 which is varied in accordance with the pressure of the air in inlet 11, the resistance 148, which is varied in accordance with the quantity of fuel flowing thru restriction 45, the resistance 91, which is manually variable to control the fuel to air ratio, and the resistance 143, which is variable in accordance with the pressure in the intake manifold of the engine.

These five resistances are proportioned with respect to each other so that the resistances 32 and 148 predominate. The resistance 32 decreases with increasing air flow, so that an increased air flow results in an increased current flowing thru the coil 52 and a consequent increase in fuel flow. The increased fuel flow acts thru the controller 150 to increase the resistance 148 and thereby reduce the current flow thru coil 152. An increase in air flow therefore causes an increase in the current flowing thru coil 52, which results in an increase in the fuel flow and thereby in an operation of resistance 148 to again decrease the current thru coil 52. The increase of resistance 148, altho proportional to the decrease of resistance 32, is less than that decrease, so that the net result is an increase in the current flow thru coil 52 and hence an increase in the fuel flow thru valve 44. Furthermore variations in fuel flow thru the restriction 45 due to extraneous causes produce a corrective effect in the current flow thru coil 52 which tends to reduce or eliminate such variations.

The pressure differential between inlet 11 and the throat of venturi 12 is a measure of the velocity of the air passing thru the carburetor, rather than the mass of that air. If the density of the air decreases, and the mass of the air passing thru the carburetor remains constant, the velocity of the air must increase to maintain the constant mass, thus causing the pressure differential between the inlet 11 and the throat of venturi 12 to increase and thereby causing a decrease in resistance 32. Since the object of this system is to proportion the mass of the air to the mass of the fuel, the system must be compensated for those variations in resistance 32 which are caused by variations in density of the air. This compensation is provided by the resistance 42, which is increased in response to a decrease in density of the air so as to counterbalance the decrease in resistance 32 caused by the decrease in the air density.

A mixture control 87 is provided so that the current flow thru coil 52 may be manually varied by moving contact 90 along resistance 91. By manipulation of the mixture control 87, the fuel to air ratio obtained with a given air flow may be varied at the will of the operator.

The resistance 143 is varied in accordance with the pressure existing in the air induction system at a point downstream from the throttles 15. This point is illustrated in the drawing as being in the mixture outlet 17, but it may with equal or even greater facility be located in the intake manifold of the engine. As the pressure in the mixture outlet 17 increases, the contact 42 is moved to the left along resistance 143, thereby decreasing the resistance 143 and increasing the fuel to air ratio. Since the pressure in the mixture outlet 17 varies substantially directly as the power output of the engine, it may be seen that the resistance 143 acts to enrich the fuel and air mixture as a function of the power required from the engine. It has been found that engines operate with less tendency to overheat at high power outputs if they are supplied with a rich fuel and air mixture than if the mixture is lean at such times. The variable resistance 143 and the mechanism which operates it have been provided in the present system to insure the supply of a rich mixture under such conditions.

The motor 66 is controlled in a manner to maintain a constant absolute pressure in the mixture outlet 17. The particular pressure value which this system maintains at outlet 17 may be adjusted by any suitable means. For example, it may be adjusted by changing the position of yoke 140 which carries the stationary contacts 112 and 118. When the pressure in the outlet 17 decreases, the bellows 72 expands, thereby moving switch contact 111 into engagement with stationary contact 112. This completes an energizing circuit for field winding 68 and armature 67 of motor 66, which may be traced from the lower terminal of a battery 113 thru a conductor 114, switch contacts 111 and 112, a conductor 115, field winding 69, armature 67, and a conductor 116 to the upper terminal of battery 113. Energization of field winding 68 and armature 67 causes motor 66 to rotate in a direction to close the throttles 15, thereby causing the pressure in outlet 17 to decrease toward its former value. In response to this decrease in pressure, the contacts 111 and 112 are again separated, deenergizing motor 66.

In a similar manner, if the pressure in outlet

17 decreases, movable switch contact 117 is moved into engagement with stationary contact 118, thereby completing an energizing circuit for field winding 69 and armature 67 of motor 66. This energizing circuit may be traced from the lower terminal of battery 113 thru conductor 114, contacts 117 and 118, a conductor 120, field winding 69, armature 67, and conductor 116 to the upper terminal of battery 113. Energization of field winding 69 causes motor 66 to run in a throttle opening direction, thereby causing an increase in pressure at outlet 17.

The second circuit for controlling the current flow thru coil 52 is hereinafter termed, for purposes of identification, the auxiliary energizing circuit for that coil. This auxiliary circuit may be traced from the right hand terminal of battery 94 thru conductor 95, coil 52, conductors 166 and 131, and thence either thru conductor 135, resistance 93 and conductor 136, or thru conductor 20 132 and resistance 83 to ground connections 134 and 102 and the left hand terminal of battery 94. The resistances 93 and 83 of this auxiliary circuit are connected in parallel with the entire group of resistances in the main circuit. Therefore an increase or decrease in one of these resistances causes a change in the current flow thru coil 52 which is independent of all the resistances in the main circuit and which predominates over the variations of those resistances.

The resistance 93 is a part of the priming control 88. By movement of slider 92 to the right along resistance 93, the current flow thru coil 52 may be greatly increased, thereby increasing the fuel flow to the carburetor independently of all the other controlling conditions. The priming control 88 is used when starting the engine to secure a very rich mixture.

The resistance 83 is varied by the acceleration responsive controller 77 to decrease the resistance and increase the current flow upon acceleration of the engine, and to decrease the current flow upon deceleration of the engine. By this means, the fuel supply is proportioned to the engine requirements immediately during acceleration and deceleration conditions, without waiting for the air flow measuring means, which has a comparatively great time lag, to respond.

The valve 46 is balanced against outlet pressure, so that the pressure on the downstream side of the metering restriction 45 is not affected by variations in the pressure adjacent the discharge nozzle 16. It may be said, therefore, that the valve 46 acts to regulate the pressure on the downstream side of restriction 45 so that the flow thru restriction 45 may be controlled by the operation of valve 44. The valve 46 is also operated by coil 57 to compensate for changes in the terminal voltage of battery 94. The coil 57 may also be utilized to positively cut off the flow of fuel to the engine.

The coil 57 is energized thru a circuit which may be traced from the right hand terminal of battery 94 thru conductors 95 and 121, a fixed resistance 122, a conductor 123, coil 57, a conductor 124, and ground connections 125 and 102 to the left hand terminal of battery 94. The energization of coil 57 changes when the terminal voltage of battery 94 changes. It may be seen that if the voltage of battery 94 increases, for example, the increased energization of coil 57 causes valve 46 to be moved in a closing direction, while the increased energization of coil 52 causes valve 44 to be moved in an opening direction. The opposing movements of these two valves 75

compensate each other, so that the fuel flow is not affected by variations in the voltage of battery 94.

The coil 57 is also controllable to provide a positive cut-off of the fuel flowing into the engine. The resistance 127 of cut-off control 89 is connected in parallel with resistance 122 by means of conductors 128 and 130. When control 89 is operated to reduce resistance 127, the energization of coil 57 is increased, and if contact 126 is moved all the way to the right, resistances 122 and 127 are shunted. The energization of coil 57 is thereby increased sufficiently to positively move valve 46 to closed position. Such a positive cut-off is used to stop the engine, being needed especially in case of fire or other emergency conditions. Furthermore, when the engine is regularly stopped by the use of such a fuel cut-off arrangement, the fuel supply conditions existing during the next starting of the engine are more uniform than when an ignition cut-off arrangement is used to stop the engine.

While I have shown and described in Figure 1 a direct current circuit controlled by variable resistance elements, it will be readily apparent that equivalent arrangements may be devised using alternating current. Furthermore, variable inductance or capacitance elements may be used in place of the variable resistance elements illustrated in Figure 1.

Figures 2 and 3

There is shown in Figure 2 a portion 200 of a carburetor body including an air passage 201 having a venturi 202 therein. A plurality of impact tubes 203 conduct a portion of the air entering the passage 201 to a vent ring 204 and thence to a distributing conduit 205. A portion of the air then flows thru a boost venturi 206, a selector valve 207 and a conduit 208 to the throat of main venturi 202. Air entering the distributing conduit 205 may flow thru any one of three removable restrictions 210, 211, and 212. Air passing thru the restriction 210 flows over an electrical resistance element 213 mounted in a chamber 214 and then thru a conduit 215 to a point in the passage 201 on the downstream side of throttle 216. Air flowing thru the restriction 211 passes over an electrical resistance element 217 mounted in a chamber 218, and thence thru a conduit 220, a chamber 221 and conduits 222 and 223 to the throat of boost venturi 206, and thence thru selector valve 207 and conduit 208 to the throat of main venturi 202. The flow of air from chamber 218 to chamber 221 is controlled by a valve 225 positioned by a bellows 226. The bellows 226 may be filled with nitrogen or other suitable temperature responsive material so that the valve 225 is operated as a function of the pressure and temperature of the air flowing thru passage 201. Air flowing thru passage 212 flows over an electrical resistance element 227 positioned in a chamber 228 to conduit 222 and thence in the same manner as the air which enters conduit 222 from chamber 221.

The restrictions 210, 211, and 212 are formed in removable plugs in order that they may be readily changed in the event that it is desired to vary the ratio between the quantities of air flowing thru the several restrictions.

In case it is desired not to use the boost venturi, the selector valve 207 may be rotated 90 degrees clockwise from the position shown in the drawing, whereupon the air entering conduit 222

flows out thru a conduit 209, valve 207 and conduit 208 to the throat of venturi 202. At the same time, a valve 219, located in conduit 223 and operatively connected to valve 207, is rotated so as to close conduit 223.

The resistance elements 213, 217 and 227 are connected in a Wheatstone bridge circuit which is illustrated more conventionally in Figure 3. This bridge circuit has a pair of input terminals 230 and 231 which are connected by conductors 232 and 233 respectively to the terminals of a battery 234. The bridge circuit also has output terminals 235 and 236, which are connected to input terminals 261 and 262, respectively, of an electronic amplifier generally indicated at 260.

The resistance elements 213, 217 and 227 are located in the lower right, upper right and lower left branches, respectively, of the bridge circuit, as viewed in Figure 3. The upper left branch of the bridge circuit includes a manually variable resistance 238 which serves as a mixture or fuel to air ratio control, as explained hereinafter. The bridge circuit also includes a resistance 240, along which a sliding contact 230 is moved by a controller 241 in accordance with the quantity of fuel flowing thru the carburetor, as hereinafter described. The contact 230 also serves as an input terminal of the bridge circuit. A portion of resistance 240 is connected in the lower left branch of the bridge circuit and the remainder is connected in the lower right branch, the relative magnitudes of the portions connected in the two branches being determined by the position of contact 230.

Referring again to Figure 2, it may be seen that all three of the resistance elements 213, 217 and 227 are continuously connected to the battery 234. These resistances are of some material such as nickel, having an appreciable temperature coefficient of resistance, and are so designed and proportioned with respect to the voltage applied to their terminals that they tend to heat up due to the current flowing thru them. The resistance elements are cooled, however, by the air flowing past them so that their respective resistance values vary inversely as the quantities of air flowing past them.

The quantity of air flowing past resistance element 213 depends upon the pressure differential across the throttle 216. This pressure differential varies inversely as the load on the engine, so it may be seen that the resistance of element 213 decreases when the load on the engine decreases and in general varies directly as the load on the engine, as measured by the throttle position.

The air flow past the resistance element 217 is controlled by the density of the air. It may be seen that upon increasing density, the bellows 226 tends to collapse, thereby opening the valve 225 and increasing the air flow over the resistance element 217, thereby lowering the temperature of that element and decreasing its resistance. The resistance of element 217 therefore varies inversely as the air density.

The air flow over the resistance element 227 is a measure of the quantity of air flowing thru the passage 201, and varies directly as a function of that quantity. Therefore, the resistance of element 227 varies inversely as the air flow.

In Figure 2, the fuel flows from a tank (not shown) thru a conduit 250, an engine driven fuel pump 251, a conduit 252, a gear pump 253, mechanically connected to an electrical motor 254, a metering restriction 255, a pressure regulator

256, and a conduit 257 to a discharge nozzle 253. Other suitable apparatus for supplying fuel to the engine may be used in place of nozzle 258, as for example, a direct injection mechanism or a spinner injector associated with a supercharger.

The output of pump 251 is controlled by a relief valve generally indicated at 265. The relief valve 265 includes a valve member 266 attached to a diaphragm 268. The valve member 266 is biased toward closed position by a spring 267. The diaphragm 268 separates a pair of expansible chambers 278 and 280. The pump discharge pressure is supplied to chamber 280 thru a conduit 282, and the chamber 278 is vented to conduit 205 by a conduit 269. The discharge pressure of the pump 251 is maintained at a substantially constant value by the action of relief valve 265, which value depends upon the strength of spring 267. Altho the pump 251 is illustrated as being of the rotary sliding vane type, any type of pump adaptable to provide a constant pressure output would be equally suitable.

The energization of motor 254 is controlled by amplifier 260, having input terminals 261 and 262, which are connected to the output terminals 235 and 236 of the bridge circuit shown in Figures 2 and 3, as previously described. The amplifier 260 has output terminals 263 and 264 which are connected to the motor 254.

The pressure regulator 256 includes a housing 270 divided by flexible diaphragm 271 into a pair of expansible chambers 272 and 273. The chamber 272 may be vented thru a conduit 274 to the conduit 205. The diaphragm 271 carries a valve member 275 which is balanced against outlet pressure. A spring 276 biases the valve 275 for movement toward closed position. The function of pressure regulator 256 is to maintain a substantially constant pressure on the downstream side of the metering restriction 255 regardless of the pressure in conduit 257 so that the fuel flow thru that restriction may be controlled by the pressure applied to its upstream side by the pumps 251 and 253. Since both pump relief valve 265 and the pressure regulator 256 are vented to the conduit 205, it may be seen that variations in the pressure at the inlet of passage 201 have no effect on the fuel flow. For example, an increase in atmospheric pressure would act on the pump relief valve 265 to increase the pump discharge pressure. This would be counteracted, however, by the action of the increased atmospheric pressure on the pressure regulator 256 to increase the pressure on the downstream side of restriction 255. The operation would be similar if both chamber 278 of relief valve 265 and chamber 272 of pressure regulator 256 were vented to the outlet of a supercharger supplying air to the inlet of passage 201.

The controller 241 which moves contact 230 along resistance 240 includes a bellows 284 fixed at one end to a casing 286. The interior of bellows 284 is connected thru a conduit 288 to the downstream side of the restriction 255. The interior of casing 286 outside the bellows 284 is connected thru a conduit 290 to the upstream side of restriction 255.

A restriction 282 interconnects the conduits 288 and 290. Restriction 292 may be opened or closed by a valve 294. Valve 294 is biased to closed position by a spring 296, and may be operated to open position by energization of a solenoid 298.

An energizing circuit for solenoid 298 may be traced from the left hand terminal of a battery

300 thru a conductor 301, a switch 302, a conductor 303, solenoid 298 and ground connections 304 and 305 to the right hand terminal of battery 300. Altho the battery 300 is illustrated as being separate from the battery 234, it is preferable to use the same source of power for all the electric circuits in this system, so that upon failure of that source for any reason, the solenoid 298 will be deenergized.

A resistance element 306 is mounted in chamber 218 and is connected thru a conductor 308 in series with a resistance element 310 mounted in chamber 228. A series circuit including the two resistance elements 306 and 310 may be utilized to operate an indicator of the quantity of air entering the carburetor, as described below in connection with Figure 4.

Operation of Figure 2

As previously described, the relief valve 265 maintains a substantially constant pressure at the outlet of pump 251. The gear pump 253 may be used to boost this pressure and increase the fuel supply above the value determined by the discharge pressure of pump 251, or the gear pump 253 may be utilized as a fluid motor to drive the electrical motor 254 as a generator, in which case the pump 253 bucks the discharge pressure of pump 251, and reduces the fuel supply. Whether the pump 253 operates to boost or buck the discharge pressure of pump 251 is determined by the polarity (or phase, if alternating current) of the current supplied to motor 254 by amplifier 260. The magnitude of the boosting or bucking effect is determined by the magnitude of that current.

In the present instance, it is desired to use the output potential of amplifier 260 as a measure of the quantity of fuel supplied to the engine, as described hereinafter in connection with Figure 4. Furthermore, as also described in connection with Figure 4, it is desired that the amplifier output be unidirectional, in order that it may conveniently be utilized in an indicating meter.

For these reasons, I prefer to choose the spring 267 so that the discharge pressure of pump 251 is effective, when pump 253 is not operating, to supply a quantity of fuel thru restrictions 255 and 292 sufficient to operate the engine at its maximum output. The gear pump 253 is then operated to buck the discharge pressure of pump 251. When the bucking effect is at a maximum, the energization of motor 254 must be at a maximum, and the fuel flow is then at a minimum. In order to secure such a mode of operation of the amplifier, the various resistance elements in the bridge circuit are chosen so that the bridge is always unbalanced, and the degree of unbalance decreases with increasing demand for fuel flow. The magnitude of the signal applied to the amplifier input terminals, and hence the amplifier output then vary inversely as the fuel flow.

As previously described, resistance element 227 varies inversely as the quantity of air flowing thru passage 201. Therefore, when the quantity of air flowing is low, as under idling conditions, the resistance of element 227 is high. If the polarity of battery 234 is chosen as indicated by the legend in the drawing, then when the resistance of element 227 is high, the output terminal 236 is negative with respect to output terminal 235. The bridge circuit is therefore normally unbalanced in a direction such that output terminal 235 is positive with respect to output terminal 236. As the quantity of air flowing thru the carburetor

increases, this unbalance decreases due to the decrease in resistance of element 227, and the signal applied to the input terminals 261 and 262 of amplifier 260 likewise decreases. This decreases the power supplied to electrical motor 254 and hence decreases the resistance of pump 253 to the flow of fuel, thereby increasing the fuel flow in proportion to the increase in air flow. The fuel flow therefore varies inversely as resistance 227.

In accordance with the known principles of bridge circuits, a change in the resistance of element 217 has the same effect on the bridge circuit as a similar change in the resistance of element 227. As previously stated, the resistance of element 217 varies inversely with the density of the air passing thru the carburetor. Therefore an increase in density causes an increase in the quantity of fuel flowing thru the carburetor. It is believed to be readily apparent if it is desired to proportion the mass of fuel to the mass of air, the quantity of fuel must be increased as the density of the air increases. The resistance 217 effects such an increase.

The resistance of element 213 varies directly as the load on the engine as measured by the drop in pressure across the throttle 216, as previously described. The resistance element 213 is connected in a branch of the bridge circuit adjacent the branches containing elements 217 and 227, and therefore its effect on the unbalance of the bridge circuit is opposite to that of elements 217 and 227. That is, an increase in resistance of element 213 causes an increase in the quantity of fuel flowing thru the carburetor. Since the resistance of element 213 varies directly as the load on the engine, it may be seen that the effect of element 213 is to vary the fuel to air ratio directly as a function of the engine load.

The resistance 238, which is manually variable, may be utilized as a control of the fuel to air ratio. By increasing the resistance of element 238, the fuel to air ratio is increased, and by decreasing its resistance, the fuel to air ratio is decreased.

The variable resistance 240 is connected in the bridge circuit in such a manner that if contact 230 is moved to the right, the resistance of the branch of the bridge circuit containing element 227 is increased and the resistance of the branch containing element 213 is decreased. Therefore, such a movement of contact 230 causes a decrease in the quantity of fuel flowing to the engine. Such a movement of contact 230 is caused by an increase in the pressure drop across restriction 255. Therefore, it may be seen that resistance 240 is varied to change the balance of the bridge circuit in accordance with the quantity of fuel flowing to the carburetor. The resistance 240 insures that upon a change in the unbalance of the bridge circuit, the resulting change in the fuel flow is proportional to the change of air flow or other controlling conditions which initiated the changed balance condition of the bridge circuit.

The restrictions 255 and 292 are preferably so proportioned that when restriction 292 is closed by valve 294, the quantity of fuel passing thru restriction 255 alone, when pump 253 is not operated to resist the fuel flow, is the quantity of fuel necessary to supply the engine at 75% of its rated load. Therefore, it may be seen that upon failure of the power supply, the resulting deenergization of solenoid 298 causes valve 294 to close, thereby setting the fuel supply at a value to produce 75% of the rated engine output.

If it were not desired to have the amplifier

13

output unidirectional and varying in accordance with fuel flow, the bridge circuit might be arranged to be balanced at some intermediate value of fuel flow. In such an arrangement, the discharge pressure of pump 251 is chosen so as to produce the value of fuel flow at which the bridge is balanced. Then upon an increase in demand for fuel flow, the bridge is unbalanced in a sense so that motor 254 operates pump 253 to boost the fuel flow. Upon a decrease in the demand for fuel flow, on the other hand, the bridge is unbalanced in the opposite sense, so that motor 254 is driven as a generator by pump 253 acting as a fluid motor, and the fuel flow is thereby decreased.

In such an arrangement, the relief valve 265 may be designed to regulate the discharge pressure of pump 251 so that, when pump 253 is not operating, the quantity of fuel supplied to the engine is sufficient to operate the engine at 75%, for example, of its rated load. Then upon failure of the power supply for motor 254, the engine would automatically receive sufficient fuel for 75% of its rated load. This arrangement avoids the necessity for using the restriction 292 and the solenoid operated valve 294 controlling it.

Figure 4

There is illustrated in Figure 4 an indicator which is adaptable for use with the fuel supply system of Figure 2 to indicate selectively any of four engine conditions, namely (1) the quantity of fuel flowing to the engine, (2) the fuel to air ratio, (3) the horse power output of the engine, (4) the brake mean effective pressure of the engine.

In Figure 4 there is illustrated a galvanometer 320 having a pointer 321 which cooperates with four scales 322, 324, 326 and 328. The scale 322 is calibrated in terms of brake mean effective pressure, the scale 324 is calibrated in terms of horse power, the scale 326 is calibrated in terms of fuel to air ratio and scale 328 is calibrated in terms of fuel flow.

The galvanometer 320 is provided with a pair of terminals 330 and 332 to which any one of four electrical circuits may be connected, as determined by the position of a selector switch generally indicated at 334. The selector switch 334 includes a knob 336 for operating a contact bar 338 to any one of four circuit closing positions and a pointer 340 to indicate which of the four engine conditions the galvanometer 320 will read when the selector switch 334 is in each of its four positions.

When the selector switch 334 is in the extreme left position of the four positions shown in the drawing, the galvanometer circuit may be traced from galvanometer terminal 330 thru a conductor 340, amplifier output terminals 263 and 264 of an amplifier which may be the amplifier 260 of Figure 2, a conductor 342, a stationary contact 344, contact bar 338, a stationary contact 346, a conductor 347, a fixed resistance 348 and a conductor 352 to terminal 332 of galvanometer 320. As described in connection with Figure 2, the output voltage of amplifier 260 is inversely proportional to the quantity of fuel flowing to the engine. Therefore, when the circuit just traced is completed, the pointer 321 will be adjacent the upper end of its associated scales when the fuel flow is low, and near the left end of its scales when the fuel flow is high.

The scale 328 may be provided with suitable colored legends as indicated in the drawing. For

14

example, a green legend may be used to indicate that the fuel flow is at a median value suitable for cruising, a yellow legend may be used to indicate a fuel flow equal to that required for rated engine output, and a red legend may be used to indicate a fuel flow equal to or greater than that required for take-off or maximum power conditions.

When the selector switch 334 is operated to the position shown in full lines in the drawing, the circuit including the galvanometer 320 may be traced from galvanometer terminal 330 thru conductor 340, output terminals 263 and 264 of amplifier 260, conductor 342, stationary contact 352, contact bar 338, stationary contact 354, conductor 356, resistance element 310, conductor 308, resistance element 306 and conductors 358 and 350 to galvanometer terminal 332. In this circuit, the amplifier 260 introduces a potential inversely proportional to the quantity of fuel flowing, while the elements 306 and 310 introduce a resistance inversely proportional to the mass of air entering the carburetor. Therefore it may be seen that the current flow thru this circuit, as measured by the galvanometer is inversely proportional to the ratio of fuel to air in the combustible mixture supplied to the engine.

When the selector switch 334 is in the position next to the right of the full line position shown in the drawing a circuit is completed for the galvanometer which causes it to indicate the horse power output of the engine. This circuit may be traced from galvanometer terminal 330 thru conductors 340 and 360, a battery 362, a conductor 363, a stationary contact 364, a contact bar 338, a stationary contact 366, a conductor 368, resistance 310, conductor 308, resistance 306, and conductors 358 and 350 to galvanometer terminal 332. Since the potential of battery 362 is substantially constant, the current flow thru this circuit varies inversely as the resistances 306 and 310. Since the sum of these resistances varies inversely as the mass of air entering the carburetor, it may be seen that the current flow varies directly with the mass of air entering the carburetor. It has been found that the mass of air entering the carburetor may be used, without serious error, as a measure of the horse power output of the engine.

When the selector switch 334 is in the extreme right position shown in the drawing, the galvanometer circuit may be traced from galvanometer terminal 330 thru conductors 340 and 360, battery 362, conductor 363, a generator 370 driven by the engine so that its speed and voltage output are proportional to the engine speed, a contact 372, contact bar 338, a contact 374, a conductor 376, resistance 310, conductor 308, resistance 306, and conductors 358 and 350 to galvanometer terminal 332. Generator 370 is chosen so that its terminal voltage at maximum speed does not exceed that of battery 362, and it is connected in this circuit, as indicated by the legend in the drawing, so that its polarity opposes that of battery 362. Therefore, the net potential in this circuit varies inversely with the speed of the engine. The resistance in this circuit varies inversely with the mass of air entering the engine. Therefore the current flow thru this circuit is directly proportional to the mass of air entering the engine per revolution. Since the displacement of the engine cylinders is constant, this mass per revolution may be taken as an indication of the brake mean effective pressure in the engine cylinders.

Figure 5.

There is illustrated in Figure 5 another form of electrical control system for a carburetor.

In Figure 5, air enters the carburetor thru an inlet 400 and passes thru a venturi 402 and a passage 404 past a throttle 406 and a discharge nozzle 408 to an outlet 410. A portion of the air entering the carburetor passes thru impact tubes 412 and a vent ring 414 to the interior of a casing 418. A flexible bellows 42 is mounted inside casing 418, and the interior of bellows 420 is connected thru a passage 422 to the throat of venturi 402. Therefore, it may be seen that bellows 420 contracts when the pressure differential between the inlet 400 and the throat of venturi 402 increases, and expands when that pressure differential decreases.

Fuel enters the carburetor of Figure 5 from a fuel pump or other source of fuel under pressure (not shown) and passes thru a conduit 422, a metering restriction 424, a conduit 426, and past a valve 428 to the nozzle 408. The metering restriction 424, altho-shown as a single restriction for purposes of convenience, may be replaced by a more conventional jet system including several restrictions. The conduit 422 upstream from restriction 424 is connected thru a conduit 430 to the interior of a casing 432. A bellows 434 is mounted inside casing 432, and its interior is connected thru a conduit 436 to the conduit 426 downstream from the restriction 424. The pressure differential across restriction 424 controls the expansion and contraction of bellows 434, causing the bellows to contract when the pressure differential increases and to expand when the pressure differential decreases. This pressure differential may be utilized as a measure of the quantity of fuel flowing thru restriction 424.

The free end of bellows 420 is attached to a link 438 whose other end is attached to an arm 440 pivotally mounted at 442 and carrying at its opposite end an insulated contact 444. The contact 444 cooperates with a slidewire resistance 446 insulatingly mounted on a plate 448 which is also pivotally movable about the point 442. The free end of bellows 434 is connected by link 450 to the plate 448.

From the foregoing it may be seen that an increase in the air flow thru the passage 404, as measured by the pressure differential acting on bellows 420 causes an upward movement of link 438 and a counterclockwise rotation of arm 440 about pivot 442, moving contact 444 upwardly along resistance 446. Also, an increase in the fuel flowing thru restriction 424 causes bellows 434 to collapse moving link 450 downwardly and rotating plate 448 counterclockwise about pivot 442 and causing an upward movement of resistance 446 under contact 444.

When the air flow is proportional to the fuel flow, the contact 444 lies at the center of resistance 446, and when the air flow is proportionately greater than the fuel flow, contact 444 is above the center of resistance 446. Similarly, when the fuel flow is proportionately greater than air flow, the contact 444 is below the resistance 446. The resistance 446 is connected by means of conductors 452 and 454 in parallel with a fixed resistance 456. A battery 458 is connected between the midpoints of the two resistances 446 and 456. The two resistances 446 and 456 and the battery 458 form a bridge circuit of which the conductors 452 and 454 may be termed the output terminals. The conductors 452 and 454

are connected by conductors 460 and 462 respectively to the input terminals of an amplifier 464. The output terminals of amplifier 464 are connected to a reversible electric motor 466, which drives thru a gear train (not shown) a shaft 468 which is provided with an internally threaded recess at one end to receive an externally threaded valve stem 470. The valve stem 470 is held against rotation by means of a key 472 and is connected to the valve 428 which controls the flow of fuel thru conduit 426. The construction is such that upon rotation of motor 466, the valve 428 is moved longitudinally in a direction depending upon the direction of rotation of motor 466. Motor 466 rotates in a direction determined by the polarity of the amplifier output, which is in turn determined by the polarity of the amplifier input. The amplifier input polarity depends upon the position of contact 444 with respect to the midpoint of resistance 446.

The arrangement should be such that when contact 444 is above the center of resistance 446, indicating that the air flow is proportionately greater than the fuel flow, the motor 466 operates valve 428 in an opening direction, thereby increasing the fuel flow. Likewise, when contact 444 is below the center of resistance 446, motor 466 operates valve 428 in a closing direction.

While I have shown no means for compensating the system of Figure 5 for variations in air density, it will be readily understood that suitable means may be provided. For example, one portion of resistance 456 could be varied in the same manner that resistance 42 of Figure 1 is varied.

While I have illustrated a direct current bridge circuit, it should be readily apparent that alternating current could be used with equal facility if corresponding changes were made in the amplifier 464 and motor 466.

While I have shown and described certain preferred embodiments of the principles of my invention, other modifications 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 a carburetor for an internal combustion engine, in combination, a first conduit for air flowing thru said carburetor to said engine, a second conduit for fuel flowing thru said carburetor to said engine, an electrical circuit, means to vary an electrical quantity in said circuit as a function of the quantity of air flowing thru said first conduit, means operative as an incident to a change in the intake manifold pressure of said engine for additionally varying said quantity, and means responsive to said electrical quantity for controlling the flow of fuel thru said second conduit.

2. In a carburetor for an internal combustion engine, in combination, a conduit for fuel flowing thru said carburetor to said engine, two valves connected in series in said conduit for controlling the flow of fuel therethru, first electrical means for operating one of said valves in a flow increasing direction upon an increase in the energization of said electrical means, second electrical means for operating the other of said valves in a flow decreasing direction upon an increase in the energization of said second electrical means, a source of electrical energy, means for controlling the energization of at least one of said electrical means from said source in accordance with a condition indicative of the quantity of fuel needed

by said engine, and means connecting both of said electrical means to said source so that a variation in the potential of said source causes operation of said valves in opposite senses so that the fuel flow is not affected thereby.

3. In a carburetor for an internal combustion engine, in combination, a first conduit for air flowing thru said carburetor to said engine, a second conduit for fuel flowing thru said carburetor to said first conduit, a metering restriction in said second conduit, a first valve in said second conduit upstream from said restriction, first electrical means for operating said first valve, a source of electrical energy, means for controlling the energization of said first electrical means from said source in accordance with the quantity of air flowing thru said first conduit, a second valve in said second conduit downstream from said restriction for regulating the pressure therein, said second valve being substantially balanced against changes in outlet pressure so that its position is not affected by the pressure in said first conduit, second electrical means for operating said second valve, and means connecting said second electrical means to said source, said first and second electrical means being effective to operate their respective valves in opposite senses upon a variation in the potential of said source so that the fuel flow is not affected thereby.

4. In a fuel supply system for an internal combustion engine, in combination, a conduit for fuel flowing to said engine, a pump in said conduit for supplying fuel to said engine, means for regulating the output of said pump so as to maintain a substantially constant discharge pressure, a fluid motor in said conduit in series with said pump, said motor being driven in one direction by fuel flowing from said pump toward said engine, an electrical motor for applying torque to said fluid motor acting in the opposite direction so as to reduce the quantity of fuel discharged thru said fluid motor by said pump, and electrical means responsive to the quantity of air flowing to said engine for combustion purposes for controlling said motor.

5. Electrical flow controlling means comprising in combination, a fluid conduit, two valves connected in series in said conduit for controlling the flow of fluid therethru, first electrical means for operating one of said valves in a flow increasing direction upon an increase in the energization of said electrical means, second electrical means for operating the other of said valves in a flow decreasing direction upon an increase in the energization of said second electrical means, a source of electrical energy, means for controlling the energization of one of said electrical means from said source in accordance with a condition indicative of the need for operation of said flow controlling means, and means connecting both of said electrical means to said source so that a variation in the potential of said source causes operation of said valves in opposite senses so that the fluid flow is not affected thereby.

6. In a carburetor for an internal combustion engine, in combination, a conduit for fuel flowing thru said carburetor to said engine, a valve in said conduit for controlling the flow of fuel therethru, electrical means for operating said valve in a flow decreasing direction upon an increase in the energization thereof, an electrical circuit including an impedance for energizing said electrical means, and means for shunting

said impedance to reduce the flow of fuel to said engine.

7. In a carburetor for an internal combustion engine, in combination, a conduit for fuel flowing thru said carburetor to said engine, two valves connected in series in said conduit for controlling the flow of fuel therethru, first electrical means for operating one of said valves in a flow increasing direction upon an increase in the energization of said electrical means, second electrical means for operating the other of said valves in a flow decreasing direction upon an increase in the energization of said second electrical means, a source of electrical energy, means for controlling the energization of one of said electrical means from said source in accordance with a condition indicative of the quantity of fuel needed by said engine, means connecting both of said electrical means to said source so that a variation in the potential of said source causes operation of said valves in opposite senses so that the fuel flow is not affected thereby, first means for increasing the energization of said first electrical means to provide an increased fuel supply, and second means for increasing the energization of said second electrical means to reduce the flow of fuel to said engine.

8. In a fuel supply system for an internal combustion engine, a conduit for fuel flowing to said engine, an engine driven pump in said conduit for delivering fuel to said engine under pressure, a fluid motor in said conduit receiving fuel from said pump, electrical means for applying a variable load to said fluid motor to control the flow of fuel thru said conduit, means responsive to the quantity of air flowing to said engine for combustion purposes for controlling the energization of said electrical means, and means for regulating the discharge pressure of said pump to maintain said discharge pressure at a substantially constant value, said pump and said regulating means cooperating to maintain a predetermined supply of fuel to said engine upon de-energization of said electrical means.

9. In a fuel supply system for an internal combustion engine, a conduit for fuel flowing to said engine, a pump driven by said engine and connected in said conduit for delivering fuel to said engine under pressure, means for regulating the discharge pressure of said pump to maintain said discharge pressure at a substantially constant value sufficient to maintain a maximum supply of fuel, a fluid motor in said conduit receiving fuel from said pump, electrical means for applying a variable load to said fluid motor to control the flow of fuel thru said conduit, valve means for restricting the flow thru said conduit downstream from said fluid motor, means biasing said valve means to a flow restricting position, second electrical means effective when energized to operate said valve means to a flow permitting position against said biasing means, a source of electrical energy for both said electrical means, said biasing means being effective upon failure of said source to operate said valve means to its flow restricting position and thereby to limit the supply of fuel to a value sufficient to operate said engine at a predetermined proportion of its rated load.

10. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, means associated with said conduit for producing two unequal pressures whose difference is a measure

of the quantity of air flowing therethru, a second conduit for fuel flowing to said engine, a metering restriction in said second conduit, means for controlling the pressure differential across said restriction to control the fuel flow thru said conduit, a first pair of expansible chambers separated by a first movable wall, means for conveying said two unequal pressures to said chambers so that said wall is positioned in accordance with the difference of said two pressures, a second pair of expansible chambers separated by a second movable wall, means for conveying to said second pair of chambers the pressure differential across said restriction so that said second wall is positioned in accordance with said differential, a slidewire resistance member, a contact member movable along said resistance member, means connecting each of said members with one of said walls for movement therewith, and electrical means responsive to the relative positions of said members for operating said pressure differential controlling means.

11. In a fuel supply system for an internal combustion engine, a conduit for fuel flowing to said engine, means for producing an electrical potential varying as the quantity of fuel required by said engine, means responsive to said potential for controlling the flow of fuel thru said conduit, an electrical meter, a fixed resistance, and an electrical circuit including said meter, said potential producing means and said fixed resistance in series so that said meter indicates the quantity of fuel flowing in said conduit.

12. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, pump means in said second conduit having a constant discharge pressure and tending to cause a constant fuel flow thru said second conduit, means for producing an electrical potential varying inversely as the quantity of fuel required by said engine, electrical means responsive to said potential for reducing the flow of fuel thru said second conduit in accordance with the magnitude of said potential, an electrical meter, a fixed resistance, and an electrical circuit including said meter, said potential producing means and said fixed resistance in series so that said meter indicates the quantity of fuel flowing in said second conduit, said pump means being effective on failure of said electrical means to produce a predetermined flow of fuel in said conduit.

13. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, means for producing an electrical potential varying as the quantity of fuel required by said engine, an electrical meter, a fixed resistance, resistance means variable in accordance with the quantity of air flowing thru said first conduit, and switch means for selectively establishing either a first circuit including said meter, said potential producing means and said fixed resistance in series so that said meter indicates the quantity of fuel flowing in said second conduit, or a second circuit including said meter, said potential producing means and said variable resistance means in series so that said meter indicates the ratio of fuel to air supplied to said engine.

14. In a fuel supply system for an internal combustion engine, a first conduit for air flow-

ing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, means for producing an electrical potential varying as the quantity of fuel required by said engine, an electrical meter, a fixed resistance, resistance means variable in accordance with the quantity of air flowing thru said first conduit, a source of substantially constant electromotive force, and switch means for selectively establishing either a first circuit including said meter, said potential producing means and said fixed resistance in series so that said meter indicates the quantity of fuel flowing in said second conduit; a second circuit including said meter, said potential producing means and said variable resistance means in series so that said meter indicates the ratio of fuel to air supplied to said engine, or a third circuit including said meter, said constant E. M. F. source, and said variable resistance means in series so that said meter indicates the power output of said engine.

15. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, means for producing an electrical potential varying as the quantity of fuel required by said engine, an electrical meter, a fixed resistance, resistance means variable in accordance with the quantity of air flowing thru said first conduit, a source of substantially constant electromotive force, means for generating an electromotive force proportional to the speed of said engine, and switch means for selectively establishing either a first circuit including said meter, said potential producing means and said fixed resistance in series so that said meter indicates the quantity of fuel flowing in said second conduit; a second circuit including said meter, said potential producing means and said variable resistance means in series so that said meter indicates the ratio of fuel to air supplied to said engine; a third circuit including said meter, said constant E. M. F. source, and said variable resistance means in series so that said meter indicates the power output of said engine, or a fourth circuit including said meter, said generating means and said variable resistance means in series so that said meter indicates the brake mean effective pressure in said engine.

16. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, an electrical meter, resistance means variable in accordance with the quantity of air flowing thru said first conduit, a source of substantially constant electromotive force, means for generating an electromotive force proportional to the speed of said engine, and switch means for selectively establishing either a first circuit including said meter, said constant E. M. F. source, and said variable resistance means in series so that said meter indicates the power output of said engine, or a second circuit including said meter, said generating means and said variable resistance means in series so that said meter indicates the brake mean effective pressure in said engine.

17. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, means for producing an electrical potential varying inversely as the quantity of fuel required by said engine, means responsive to said potential for controlling the flow of fuel thru said second

conduit, an electrical meter, a fixed resistance, resistance means variable inversely in accordance with the quantity of air flowing thru said first conduit, a source of substantially constant electromotive force, means for generating an electromotive force less than said constant force and proportional to the speed of said engine, and switch means for selectively establishing either a first circuit including said meter, said potential producing means and said fixed resistance in series so that said meter indicates the quantity of fuel flowing in said second conduit; a second circuit including said meter, said potential producing means and said variable resistance means in series so that said meter indicates the ratio of fuel to air supplied to said engine; a third circuit including said meter, said constant E. M. F. source, and said variable resistance means in series so that said meter indicates the power output of said engine, or a fourth circuit including said constant E. M. F. source and said generating means in series opposition, and said meter and said variable resistance means in series therewith so that said meter indicates the brake mean effective pressure in said engine.

18. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, means for producing an electrical potential varying inversely as the quantity of fuel required by said engine, an electrical meter, resistance means variable inversely in accordance with the quantity of air flowing thru said first conduit, and an electrical circuit including said meter, said potential producing means and said variable resistance means in series so that said meter indicates the ratio of fuel to air supplied to said engine.

19. In a fuel supply system for an internal combustion engine, a conduit for air flowing to said engine for combustion purposes, resistance means variable inversely in accordance with the quantity of air flowing thru said first conduit, a source of substantially constant electromotive force, an electrical meter, and an electrical circuit including said meter, said source, and said variable resistance means in series so that said meter indicates the power output of said engine.

20. In a fuel supply system for an internal combustion engine, a conduit for air flowing to said engine for combustion purposes, resistance means variable inversely in accordance with the quantity of air flowing thru said first conduit, means for generating an electromotive force proportional to the speed of said engine, an electrical meter, and an electrical circuit including said generating means, said meter, and said resistance means in series so that said meter indicates the brake mean effective pressure in said engine.

21. In a fuel supply system for an internal combustion engine, a conduit for fuel flowing to said engine, means for producing an electrical potential varying as the quantity of fuel required by said engine, means responsive to said potential for controlling the flow of fuel thru said conduit, an electrical meter, and an electrical circuit including said meter and said potential producing means so that said meter indicates the quantity of fuel flowing in said conduit.

22. In a fuel supply system for an internal combustion engine, a first conduit for air flowing to said engine for combustion purposes, a second conduit for fuel flowing to said engine, pump

means in said second conduit having a constant discharge pressure and tending to cause a constant fuel flow thru said second conduit, means for producing an electrical potential varying inversely as the quantity of fuel required by said engine, electrical means responsive to said potential for reducing the flow of fuel thru said second conduit in accordance with the magnitude of said potential, an electrical meter, and an electrical circuit including said meter and said potential producing means so that meter indicates the quantity of fuel flowing in said conduit, said pump means being effective on failure of said electrical means to produce a predetermined flow of fuel in said conduit.

23. A carburetor for an internal combustion engine, comprising a first conduit for combustion air flowing to said engine, a second conduit for fuel flowing to said engine, an electrical circuit, Venturi means in said first conduit for establishing two unequal pressures whose difference is a measure of the velocity of flow of air therethru, a secondary air conduit in parallel with said Venturi means and having a flow of air induced therethru by the difference of said two pressures, a valve in said secondary conduit, a resistance element connected in said circuit and positioned in said secondary air conduit to be cooled by the flow of air therethru, means responsive to the density of the flowing air for operating said valve so as to vary the resistance of said element as a function of said density, and means responsive to the current flow thru said circuit for controlling the flow of fuel thru said second conduit.

24. In a charge forming device for internal combustion engines, fuel passage means for supplying fuel to the engine having means therein for setting up a differential of pressures proportional to fuel flow therethrough, air passage means for supplying air to the engine having means therein for setting up a differential of air pressures proportional to air flow therethrough, pressure-electric units having their pressure elements responsive respectively to said differential of air and fuel pressures, and valve means for controlling the fuel flow through said fuel passage means having electro-responsive operating means governed by the electric elements of said units to provide a predetermined fuel air ratio, the electric elements of said pressure-electric units comprising resistance members having a resistance which increases progressively along the length thereof, and said pressure elements each comprising a pressure responsive diaphragm carrying a contact element longitudinally slidable on said resistance.

25. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a pump in said conduit for supplying fuel to said engine, means for regulating the output of said pump so as to maintain a substantially constant discharge pressure, a fluid motor in said conduit in series with said pump, said motor being driven in one direction by fuel flowing toward said engine, an electrical motor for applying to said fluid motor a torque acting in the opposite direction so as to reduce the flow of fuel through said fluid motor, and electrical means responsive to a condition indicative of the power output of said engine for controlling said electrical motor.

26. A fuel supply system for an internal combustion engine, comprising a conduit for fuel flowing to said engine, a pump in said conduit for supplying fuel to said engine, means for regulating the output of said pump so as to maintain a sub-

stantially constant discharge pressure, a fluid motor in said conduit in series with said pump, said motor being driven in one direction by fuel flowing toward said engine, an electrical motor for applying to said fluid motor a torque acting in the opposite direction so as to reduce the flow of fuel through said fluid motor, and electrical means responsive to an operating condition of said engine for controlling said electrical motor.

27. A fuel supply system for an internal combustion engine, comprising a conduit for combustion air flowing to said engine, a throttle for controlling the flow of air through said conduit, a conduit for fuel flowing to said engine, an electrical circuit, means for varying an electrical quantity in said circuit as a function of the rate of flow of air through said air conduit, means responsive to the pressure in said air conduit at a point downstream from said throttle for varying said electrical quantity, and means responsive to said electrical quantity for controlling the flow of fuel through said fuel conduit.

28. A fuel supply system for an internal combustion engine, comprising a conduit for combustion air flowing to said engine, a conduit for fuel flowing to said engine, an electrical circuit, first means for varying an electrical quantity in said circuit in accordance with the rate of flow of air through said air conduit, second means for varying said electrical quantity in accordance with the density of the air in said air conduit, third means for varying said electrical quantity in accordance with the pressure in the intake manifold of said engine, fourth means for varying said electrical quantity in accordance with the position of a manually movable control member, fifth means for varying said electrical quantity in accordance with the rate of flow of fuel through said fuel conduit, and means responsive to said electrical quantity for controlling the flow of fuel through said fuel conduit.

29. A fuel supply system for an internal combustion engine, comprising a conduit for combustion air flowing to said engine, a conduit for fuel flowing to said engine, an electrical circuit, means responsive to the magnitude of a unidirectional electrical quantity in said circuit for controlling the flow of fuel through said fuel conduit, first means for varying the magnitude of said electrical quantity in accordance with the rate of flow of air through said air conduit and effective to vary said magnitude in a fuel flow increasing sense in response to an increase in the rate of air flow, and second means for varying the magnitude of said electrical quantity in accordance with the volume of fuel flowing through said fuel conduit per unit time and effective to vary said magnitude in a fuel flow decreasing sense in response to an increase in the rate of flow of fuel.

30. In a charge forming device for internal combustion engines, fuel passage means for supplying fuel to the engine having orifice means

therein for setting up a differential of fuel pressures, air passage means for supplying air to the engine having a venturi therein for setting up a differential of pressures proportional to air flow therethrough, valve means for controlling the fuel flow to said orifice means, electro-responsive means for operating said valve means, pressure-electric units having electric elements controlling the energization of said electro-responsive means and having their pressure elements responsive to pressure changes and to temperature changes in the air in said venturi, to said differential of fuel pressures and to said differential of air pressures.

31. In a charge forming device for an internal combustion engine, fuel metering means for setting up a differential of fuel pressures, air metering means for setting up a differential of air pressures, valve means for controlling the flow of fuel to said fuel metering means, an electric circuit, pressure-electric means having their electric elements connected in said circuit and having their pressure elements controlled by said fuel and air differential pressures and by the temperature of the charging air, and electro-responsive means for actuating said valve means energized upon changes in temperature and pressure affecting the electric elements of said pressure-electric means.

LEIGHTON LEE, II.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,437,626	Wilson	Dec. 5, 1922
1,826,762	Franklin	Oct. 13, 1931
1,849,335	Schmidt	Mar. 15, 1932
2,004,869	Hogg	June 11, 1935
2,224,472	Chandler	Dec. 10, 1940
2,228,000	Chandler	Jan. 7, 1941
2,250,932	Kittler	July 29, 1941
2,281,411	Campbell	Apr. 28, 1942
2,295,656	Hersey et al.	Sept. 15, 1942
2,303,998	Thompson	Dec. 1, 1942
2,305,912	Holley, Jr.	Dec. 22, 1942
2,310,984	Mock et al.	Feb. 16, 1943
2,330,650	Weiche	Sept. 28, 1943
2,341,257	Wunsch	Feb. 8, 1944
2,348,113	Davis	May 2, 1944
2,372,766	Colvin et al.	Apr. 3, 1945
2,395,648	Teichert	Feb. 26, 1946

FOREIGN PATENTS

Number	Country	Date
442,497	Great Britain	May 3, 1934
523,895	Great Britain	July 25, 1940
543,260	Great Britain	Feb. 17, 1942
549,249	Great Britain	Nov. 12, 1942
822,090	France	Dec. 20, 1937