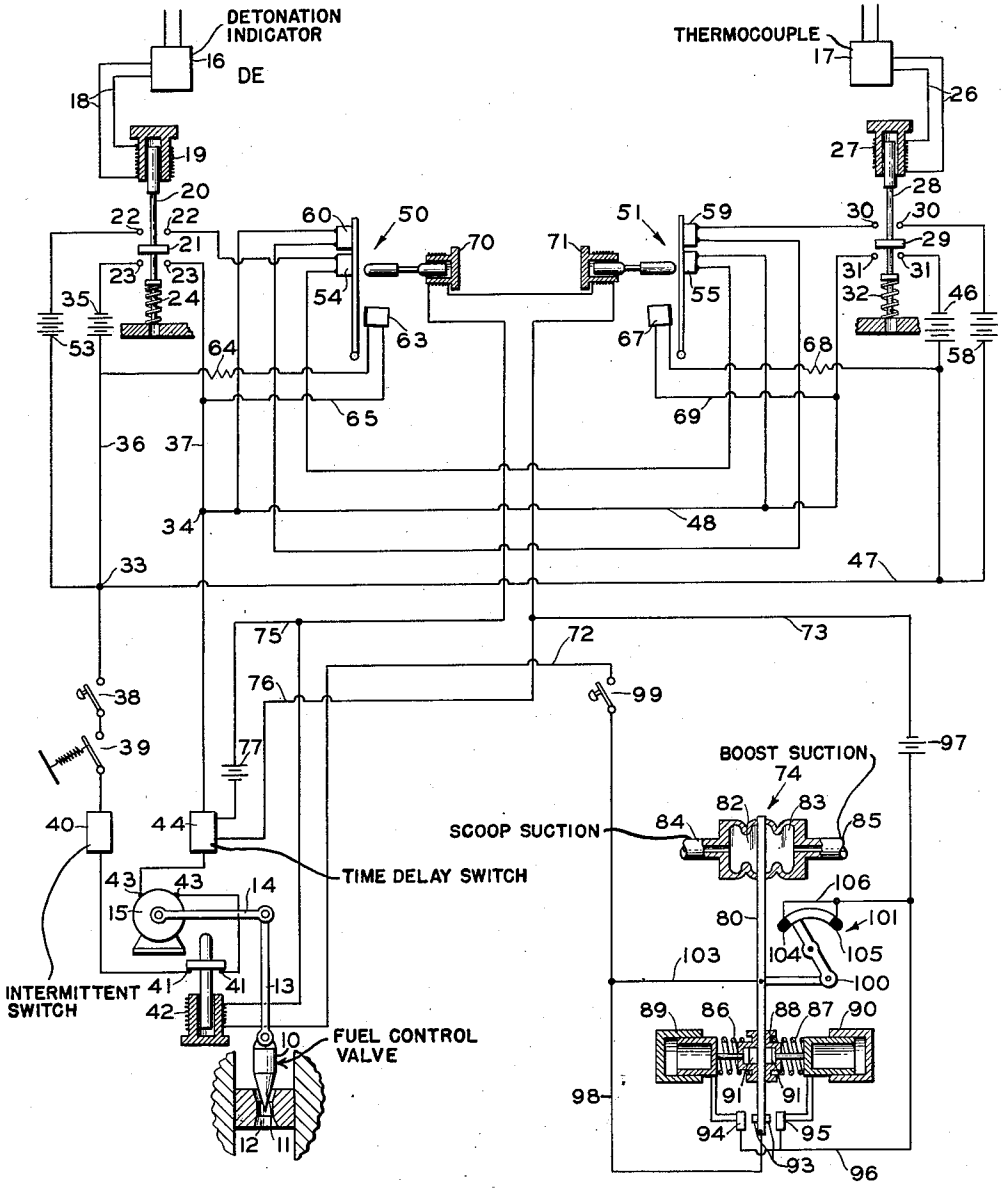
Dec. 16, 1952 E. A. MALICK 2,621,642

FUEL METERING CONTROL

Filed April 20, 1948 2 SHEETS—SHEET 1

FIG. 1



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FUEL METERING CONTROL

Filed April 20, 1948 2 SHEETS—SHEET 2

FIG. 2

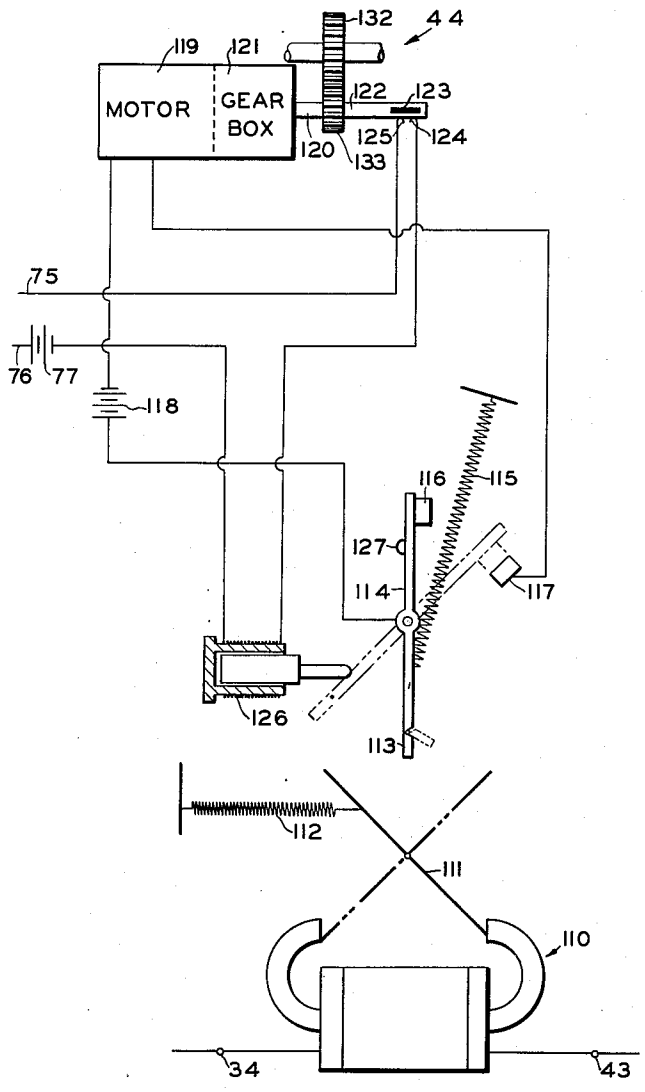
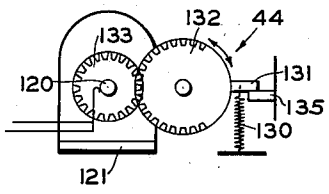


FIG. 3



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UNITED STATES PATENT OFFICE

2,621,642

FUEL METERING CONTROL

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Application April 20, 1948, Serial No. 22,170

13 Claims. (Cl. 123—119)

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This invention relates to a fuel metering system for automatically regulating the fuel-air ratio in a fuel mixture supplied to an internal combustion engine.

Carburetors utilized in aircraft and other internal combustion engines are designed to provide a predetermined fuel-air ratio at each engine power, and the engine power is generally proportional to air flow. Within the idling range of the engine, the fuel-air ratio is decreased in a linear manner as the power is increased. In the cruising range, the fuel-air ratio remains substantially constant as the power is increased while, in the high power range, the fuel-air ratio is progressively increased as the power is increased, in accordance with a function determined by the engine design, the fuel to be used, and other factors. Finally, at extremely high powers, the fuel-air ratio is again substantially constant as the power is increased.

In the high power range, the fuel mixture must be enriched as the power is increased in order to prevent an excessive increase in engine temperature and in order to suppress detonation. This is ordinarily done by designing the carburetor so as to supply a sufficiently rich fuel mixture that neither detonation nor excessive engine temperatures are encountered, regardless of the temperature or other conditions under which the engine is operated. In the usual carburetor, two settings are provided, one for a rich fuel mixture, and the other for a lean fuel mixture. However, any fuel metering structure which will permit only a finite number of fuel-air ratios, at a given engine power in the high power range, will introduce compromises affecting either fuel economy or engine reliability and life, or both simultaneously. It is also apparent that the smaller the number of selective fuel-air ratios, the greater becomes the degree of compromise which must be accepted. Accordingly, at each power within the high power range, the carburetor maintains a fixed fuel-air ratio in the rich setting, and sometimes in the lean setting, which is high enough to prevent detonation and excessive engine temperatures under the worst conditions which could be encountered in operation of the engine.

It will be apparent that substantial savings in fuel may be effected by providing means for automatically adjusting the fuel-air ratio to the

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optimum value for prevailing engine and atmospheric conditions. This would enable the use of a leaner mixture than that provided by the carburetor under most operating conditions. As an example, low atmospheric temperatures will cause the engine temperatures and the tendency toward detonation to decrease thereby enabling the use of a leaner fuel-air mixture. In addition, variations in the characteristics of the fuel, spark setting, valve timing, and other factors also permit the use of a leaner mixture. Further, the use of unnecessarily rich mixtures, as frequently introduced by present carburetors under ordinary operating conditions, oftentimes causes torching of the exhaust, or substantial power losses resulting from introduction of excessive fuel to the engine cylinders. Torching may result in damage to the exhaust collector pipe or adjacent parts, and is very disadvantageous in many respects, particularly in the operation of military aircraft, since it permits such aircraft to be readily detected at night.

It is an object of my invention to eliminate the problem of fixed fuel-air ratios by varying the fuel-air ratio as a function of the requirements for suppression of detonation or maintenance of proper engine temperature, particularly in the high power range of engine operation.

It is a further object of the invention to provide fuel metering apparatus to regulate the fuel-air ratio so that there will be no danger of detonation or overheating due to excessively lean mixtures of fuel and air.

It is a still further object of the invention to minimize the danger of torching of the exhaust or large power losses due to excessively rich mixtures.

Various other objects, advantages and features of the invention will become apparent from the following detailed description taken in conjunction with the accompanying drawings, in which:

Figure 1 is a schematic circuit diagram of my novel fuel metering apparatus;

Figure 2 is a schematic circuit diagram of a time delay unit utilized in Figure 1; and

Figure 3 is a view illustrating a feature of the circuit of Figure 2.

Referring now to the drawings in detail, and particularly to Figure 1, I have disclosed a fuel control valve 10 having a tapered portion 11

which cooperates with an orifice 12 to control the delivery of fuel to the cylinders of an internal combustion engine and thereby to vary the fuel-air ratio. In some instances, a rotary or other type of valve may be substituted for the structure shown. A lever 13 is pivoted to the valve 10 and this lever is pivoted, in turn, to an arm 14 which may be rotated by a reversible electric motor 15. The construction of the motor and valve is such that rotation of the motor in one direction opens the valve 10 and thereby enriches the fuel mixture whereas rotation of the motor in the opposite direction closes the valve 10 and leans out the fuel mixture.

The operation of the motor is controlled jointly by a detonation meter 16 and a thermocouple 17 which constitute, respectively, devices for sensing detonation in one or more cylinders of the engine and for sensing engine temperature. A suitable detonation meter is shown in the copending application of D. R. de Boisblanc, Serial No. 548,757, filed August 9, 1944, now Patent No. 2,448,323, issued August 31, 1948, and it will be understood that this meter provides an electrical current, the voltage of which is representative of the intensity of detonation in one or more engine cylinders. The thermocouple 17 may be of conventional construction and constitutes a device for providing an electrical current which is proportional to some desired indication of the engine temperature, such as the temperature of the cylinder heads or cylinder bases.

The electrical output of the detonation meter 16 is fed through conductors 18 to the coil of a solenoid 19. The core 20 of the solenoid carries a contact bar 21 which is engageable with two contact sets 22 and 23, the contacts 23 being closed when detonation of a predetermined intensity is occurring in the cylinder, and the contacts 22 being closed when no detonation is occurring in the cylinder. The core 20 is biased inwardly toward the solenoid 19 by a spring 24 so that, under certain conditions, the bar 21 may occupy a position intermediate the contacts 22 and the contacts 23.

A unit similar to that already described in connection with the detonation meter 16 is provided for the thermocouple 17. This unit includes conductors 26 for feeding the electrical output of the thermocouple to the coil of a solenoid 27, the core 28 of which carries a bar 29 which is engageable with a set of contacts 30 when the engine temperatures are too low and which is engageable with a set of contacts 31 when the engine temperatures are too high, the core 28 being biased toward the solenoid 27 by a spring 32 so that the bar may occupy a position intermediate the contacts 30 and 31 when the engine temperature is within a predetermined operating range.

When excessive detonation occurs in the cylinder of the engine, contacts 23 are closed and a voltage is applied across a set of terminals 33, 34 by a circuit which includes contacts 23, a current source 35, a conductor 36 and a conductor 37. The voltage appearing across terminals 33, 34 is applied to the motor 15 through a main control switch 38, a thermostatic switch 39, an intermittent switch 40, the contacts 41 of a solenoid 42, motor terminals 43, and a time delay switch 44. Assuming that all of the switches are closed, the voltage across terminals 33, 34 causes operation of the motor in the proper direction to slowly open valve 10 in a progressive manner, thereby continuously enriching the fuel mixture fed to the engine until the detonation ceases. Thereupon, contact bar 21 is disengaged from contacts 23 and the motor circuit is broken. Similarly, when high engine temperatures are encountered, the bar 29 engages contacts 31 thereby applying a voltage across terminals 33, 34 through a circuit which includes contacts 31, a current source 46, a conductor 47, and a conductor 48, this voltage causing operation of the motor 15 in the proper direction to open the valve 10 and enrich the fuel mixture until the excessive engine temperatures are lowered. Thereupon, contact bar 29 is disengaged from contacts 31 and the motor circuit is broken.

Similar circuits are provided for causing rotation of the motor 15 in opposite direction when excessively low engine temperatures are encountered or when no detonation occurs in the engine cylinder so that the valve 10 is progressively closed to lean out the fuel mixture. These circuits, however, differ from those already described in that they are disabled by energization of either one of a pair of relays 50 and 51, for reasons to be hereinafter explained in detail. Thus, when no detonation is occurring, the bar 21 closes a circuit which includes a current source, 53, contacts 22, normally closed contacts 54 of relay 50, normally closed contacts 55 of relay 51, and the conductor 48. Although contacts 54, 55 are referred to as normally closed contacts for convenience, it will be noted that they are not biased to closed position. Assuming that both sets of relay contacts are closed, as shown, a voltage is applied across terminals 33 and 34 which is of the proper polarity to operate motor 15 in such direction as to close the valve 10 and lean out the fuel mixture.

Similarly, when the engine temperature becomes too low, contact bar 29 engages contacts 30 thereby closing a circuit which includes a current source 58, contacts 30, normally closed contacts 59 of relay 51, normally closed contacts 60 of relay 50, terminals 33, 34 and the conductor 47. Assuming that the contacts of relays 50 and 51 are closed, this circuit applies a voltage across terminals 33 and 34 which causes the motor 15 to operate in the proper direction to close valve 10 and lean out the fuel mixture.

It will be noted that relay 50 is provided with a coil 63 which is connected in circuit with a resistor 64, current source 35, contacts 23, and a conductor 65. Accordingly, when detonation occurs in a cylinder, and contacts 23 are closed to enrich the fuel mixture, the coil 63 is energized and the relay 50 is actuated to open contacts 54 and 60. This disables the described circuits for leaning out the fuel mixture until contacts 54 and 60 are again closed in the manner hereinafter described. Similarly, the relay 51 is provided with a coil 67 which is connected in circuit with a resistor 68, current source 46, contacts 31, and a conductor 69. Accordingly, when contacts 31 are closed responsive to excessive engine temperatures, and the valve 10 is operated to enrich the fuel mixture, the coil 67 is energized thereby operating relay 51 and breaking contacts 55 and 59. This disables both leaning out circuits until the contacts 55, 59 are again closed in the manner hereinafter described.

The relays 50 and 51 have a pair of solenoids 70 and 71 associated therewith, respectively, and each solenoid, when actuated, moves the armature of its associated relay so as to close the normally closed relay contacts. The coils of the solenoids 70, 71 are connected in series with each other and with the coil of the solenoid 42. When

the latter solenoid is energized, the valve operating lever 14 is rotated a sufficient distance in a counter-clockwise direction to completely open valve 10 and provide a rich fuel mixture for the engine. The extent of richness can be limited to the rich setting of the carburetor if desired, or a value slightly richer than that provided by the rich setting of the carburetor. The solenoids 42, 70 and 71 are all actuated simultaneously when current is fed to the coils thereof through a pair of conductors 72, 73 forming a part of a power change sensing unit 74. Solenoids 70 and 71 are energized without actuation of solenoid 42 when current is supplied through conductors 75, 76 from battery 77 and the time delay switch unit 44, the operation of which will be further described hereinafter. It will be understood that energization of solenoids 70, 71 by either of the described circuits causes closure of contacts 54, 60 and contacts 55, 59 with the result that the leaning out circuits controlled by contacts 22 and contacts 30 are in readiness for operation should the engine temperature fall below a predetermined value and no detonation be present in the engine cylinder, or cylinders, to which detonation meter 16 is attached.

The power change sensing unit 74 includes a control lever 80 which is moved laterally when a pressure differential exists between two bellows chambers 82 and 83. In the case of an aircraft engine, chamber 82 may be connected through line 84 with compensated or uncompensated scoop suction and chamber 83 may be connected through a line 85 with boost suction. The term "boost suction" herein refers to suction forces created by a small venturi located within the main one, exit being near the throat of the main venturi so as to augment the suction. Similarly, the term "compensated or uncompensated scoop suction" refers to corrected metering forces below prevailing atmospheric pressure which is obtained by the automatic mixture control compensating for changes in barometric pressure with changes in airplane altitude. Accordingly, the displacement of lever 80 is proportional to the pressure differential between chambers 82, 83 which, in turn, is proportional to the power level of the engine. A pair of springs 86, 87 are connected, respectively, between a collar 88 carried by the control lever and a pair of dash pots 89 and 90. Each of the dash pots is mechanically connected through a lost-motion connection 91 to the collar 88 so that sudden movements of the control unit 80 are effectively sensed.

A set of contacts 93 is carried by control lever 80, this set of contacts cooperating with contacts 94, 95 which are mounted on the respective dash pot units 89, 90 and which are interconnected by a conductor 96 leading to one terminal of a current source 97, the other terminal of which is connected to conductor 73. The contacts 93 are connected by a conductor 98 and a switch 99 to conductor 72. The movable arm 100 of a switch 101 is mechanically connected to the control lever 80 by a link 102 and electrically connected to the conductor 98 by a lead 103. The switch includes two stationary contacts 104, 105 and these contacts are interconnected by a wire 106 which leads to the conductor 96.

When the engine is operating within a predetermined power range, arm 101 is positioned between contacts 104, 105 and switch 101 is open. If the engine power rises above or falls below this predetermined range, either contacts 100, 104 or 100, 105 are closed with the result that solenoids 42, 70 and 71 are energized. Accordingly, relays 50, 51 are reset, arm 14 is raised to feed a rich mixture to the carburetor, and the automatic control system is disabled until switch 101 is opened. This occurs when the power level of the engine is once again within the predetermined range of automatic operation. Preferably and advantageously, this predetermined power range corresponds to the well-known high power range of the engine.

When the engine power is within the predetermined range and switch 101 is open, power changes occur frequently which are of insufficient magnitude to close switch 101. Such power changes effect momentary closure of contacts 93, 94 or 93, 95 depending upon whether the power is increased or decreased, the closure of said contacts causing a momentary energization of solenoids 42, 70 and 71. For example, if lever 80 moves toward dash pot 90, lost motion connection 87 permits momentary engagement of contacts 93 and 95. After such momentary engagement, contact 95 is moved away from contact 93 by the spring 87. Contacts 93, 94 are momentarily closed in a similar manner by movement of lever 80 toward dash pot 89.

Accordingly, each time the circuit between conductors 72, 73 is closed by operation of the power change sensing unit 74, relays 50, 51 are reset by solenoids 70, 71 so that a leaning out cycle may occur upon de-energization of solenoids 42, 70, 71 and upon closure of contacts 30 due to low engine temperature or upon closure of contacts 22 due to absence of detonation.

Solenoid 42 is also operated to disable the automatic control system and open valve 10 each time unit 74 is actuated. The operation of the solenoid is momentary if either contacts 93, 94 or 93, 95 is closed but the solenoid is continuously energized if the engine power is not within the predetermined range of automatic operation, as indicated by closure of contacts 100, 104 or 100, 105.

The time delay switch 44 is an optional feature and serves to reset relays 50 and 51 a predetermined interval after each enriching cycle to permit establishment of a subsequent leaning out cycle before a power change occurs. Thus, when contacts 23 or contacts 31 are closed to cause operation of the motor 15 and enrich the fuel mixture, it has been previously pointed out that either relay 50 or relay 51 is operated to prevent a subsequent leaning out cycle until the relay is reset by operation of power change sensing unit 74. Ordinarily, power changes occur with sufficient frequency that it is not necessary to provide for the case where a leaning out cycle should occur after an enriching cycle but prior to the next operation of power change sensing unit 74. However, in some cases, this result is desirable and it may be effected by the use of time delay switch 44.

The operation of switch 44 is to reset relays 50 and 51 without operating solenoid 42, this action occurring a predetermined interval after an enriching cycle resulting from closure of contacts 23 or contacts 31. A suitable circuit arrangement for accomplishing this result is shown in Figures 2 and 3 wherein it will be noted that a polarized relay 110 is connected in the circuit between the terminal 34 and a motor terminal 43 of Figure 1. The armature 111 of the relay is biased to the full line position shown in Figure 2 by a spring 112 and, when current flows

through the relay in such direction as to cause the motor 15 to lean out the fuel mixture, the relay 110 is not actuated. However, when current flows through the relay in such direction as to cause motor 15 to enrich the fuel mixture, relay 110 is actuated and the armature 111 moves to the dotted line position of Figure 2, thereby engaging a hinged portion 113 of a snap action switch member 114. The switch 114 is not actuated by this movement of the armature since the hinged portion 113 merely swings out of the path of the armature. However, when the enriching cycle is completed, the current flowing through relay 110 is cut off and the armature is returned to its full line position by spring 112, so that it again engages the hinged portion 113. The member 114 is provided with an overcenter spring 115 so that the second engagement of the portion 113 by the armature 111 causes a contact 116 to move by snap action into engagement with a contact 117. This closes a circuit including a current source 118 and a motor 119 thereby causing the motor to rotate a shaft 120 through a gear box 121. A drum controller unit 122 is rotatable with the shaft and, after a predetermined interval, a conducting shoe 123 of the controller bridges contacts 124 and 125, thereby completing a circuit through conductors 75 and 76, the current source 77, and a solenoid 126.

The resultant energization of solenoid 126 moves the member 114 in a counter-clockwise direction into engagement with a stop 127, thereby breaking the circuit between contacts 116, 117 to stop rotation of the motor 119. When the motor 119 is stopped by the opening of contacts 116 and 117, the shaft 122 is returned to its original position by a spring 130, Figure 3, which is secured to an arm 131 protruding from a gear 132 which meshes with a gear 133 fixed to the shaft 120. In its original position of the motor, arm 131 engages a stop 135 and the force exerted by spring 130 is sufficient to return the motor to this position after it has been operated.

Accordingly, each time the reversible motor 15 is operated to enrich the fuel mixture, the relay 110 of time delay unit 74 is operated at the end of the enriching cycle and, after a predetermined time interval, contacts 124, 125 are closed with the result that solenoids 70 and 71, Figure 1, are energized to reset relays 50 and 51 for a subsequent leaning out cycle. In some instances, this permits substantial fuel savings, particularly where operation of the engine is such that power changes are of infrequent occurrence.

As an optional feature, I may also provide a thermostatic switch 39 which disables the control system should the engine carburetor, air, or mixture temperature rise to an unsafe value due to abnormal flight or weather conditions. As an additional optional feature, I may provide the intermittent switch 40, which may simply be a constantly driven drum controller, to periodically interrupt the current supplied to motor 15 in order to prevent the enrichment or leaning out of the fuel mixture to exceed the limits set up by the setting of contacts 22, 23, 30, and 31.

From the foregoing description, the operation of the complete system will now be apparent to those skilled in the art. Assuming that main control switches 38 and 99 are closed and that the engine is operating within the predetermined power range determined by the setting of switch 101, whenever the engine temperature becomes excessive or whenever detonation of more than a predetermind amplitude occurs in the cylinder or cylinders associated with detonation meter 16, contacts 23 or contacts 31 are closed to effect operation of the motor 15 and thereby enrich the fuel mixture to overcome such detonation or excessive temperatures. When a power change occurs within said predetermined power range, the unit 74 is operated and solenoid 42 is momentarily actuated to provide a rich fuel mixture while the power change is occurring. The power change also actuates solenoids 70 and 71 to effect closure fo relay contacts 54, 55, 59, and 60. As a result, the motor 15 is operated to lean out the fuel mixture in response to subsequent closure of contacts 30 due to excessively low engine temperatures or in response to subsequent closure of contacts 22 due to absence of detonation in the engine cylinder. It will be noted, however, that if either contacts 23 or contacts 31 are closed prior to the closure of contacts 22 or contacts 30, one of the relays 50, 51 is operated to disable the leaning out circuits until the relays are reset by a subsequent actuation of power change unit 74. Optionally, time delay switch 44 may be provided to reset the relays a predetermined interval after each enriching cycle without the occurrence of a power change. When the engine power is outside the aforesaid predetermined power range, switch 101 is closed and unit 74 is continuously actuated, thereby to energize solenoids 42, 70 and 71 with the result that the automatic control system is disabled until the power level once again is within the predetermined range. The described energization of solenoids 70, 71 also closes relays 50, 51 to prepare the system for a subsequent leaning out cycle.

It will be apparent that the described system effects the metering of fuel to the engine in such fashion that the fuel-air ratio always has a proper value to prevent detonation or excessive engine temperatures while still utilizing the leanest possible fuel mixture. Such regulation of the fuel-air ratio also minimizes the disadvantages resulting from torching of the exhaust or the loss of substantial power due to supplying excessive fuel to the engine cylinders. The system of this invention also provides means for equalizing the performance of a number of engines by operating all of these engines under optimum fuel-air conditions despite unavoidable variations in the manufacture of the carburetors. Although the system has been primarily described in connection with aircraft engines, it will be obvious that many embodiments are applicable to many other types of engines, such as automobile engines. When applied to automobile engines, other power change sensing means may be utilized than the bellows chambers 82, 83 provided that control lever 80 moves in accordance with changes in the power output of the engine.

While the invention has been described in connection with a present, preferred embodiment thereof, it is to be understood that this description is illustrative only and is not intended to limit the invention, the scope of which is defined by the appended claims.

Having described my invention, I claim:

1. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for sensing detonation in a cylinder of said engine, means for sensing engine temperature, and a control unit for said valve ac-

tuated by both of said sensing means, to maintain predetermined conditions of detonation and engine temperature through regulation of the fuel-air ratio of the fuel mixture.

2. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for sensing detonation in a cylinder of said engine, means for sensing excessive engine temperatures, and a control unit for said valve actuated by both of said sensing means for enriching said fuel mixture when necessary to prevent detonation or excessive engine temperatures.

3. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for sensing detonation in a cylinder of said engine, means for sensing engine temperature, first control means to operate said valve and lean out the fuel mixture, said sensing means permitting operation of said control means only when the engine temperature is below a predetermined value or when no detonation is occurring, second control means actuated by said sensing means to operate said valve and enrich the fuel mixture when detonations occur or the engine temperature becomes excessive, means disabling said first control means upon operation of said second control means, power change sensing means, and means for restoring said first control means to operative condition upon each operation of said power change sensing means.

4. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for sensing detonation in a cylinder of said engine, means for sensing engine temperature, first control means to operate said valve and lean out the fuel mixture, said sensing means permitting operation of said control means only when the engine temperature is below a predetermined value or when no detonation is occurring, second control means actuated by said sensing means to operate said valve and enrich the fuel mixture when detonations occur or the engine temperature becomes excessive, means disabling said first control means upon operation of said second control means, power change sensing means, means for restoring said first control means to operative condition upon each operation of said power change sensing means, and a time delay unit independent of said power change sensing means to place said first control means in operative condition a predetermined interval after said second control means has been actuated.

5. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electric current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electric current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a reversible motor operatively connected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, and a second control circuit including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture.

6. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electric current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electric current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a motor operatively connected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, and a second control circuit including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture, means actuated by said first circuit for disabling said second circuit each time the former circuit is actuated, and a thermostatic switch connected in circuit with said motor to prevent operation thereof when the engine temperature is excessive.

7. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electric current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electric current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a reversible motor operatively connected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, and a second control circuit including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture, means for disabling said second circuit each time the first circuit is actuated, power change sensing means, and means actuated by said sensing means for restoring said first circuit to operative condition each time a power change occurs.

8. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electrical current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electrical current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a reversible motor operatively con-

nected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, a second control circuit including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture, a pair of relays each having a set of normally closed contacts connected in circuit with said second contacts and a set of normally closed contacts connected in circuit with said fourth set of contacts; the coils of said relays being connected in circuit, respectively, with said first set of contacts and said third set of contacts whereby the second control circuit is disabled when the first control circuit is actuated to energize one of said relays and open its normally closed contacts, power change sensing means, and solenoids actuated by said power change sensing means to close both sets of normally closed contacts each time a power change occurs.

9. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electrical current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electric current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a reversible motor operatively connected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, a second control circuit including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture, a pair of relays each having a normally closed set of contacts connected in circuit with said second contacts and a normally closed set of contacts connected in circuit with said fourth contacts, the coils of said relays being connected in circuit, respectively, with said first contacts and said third contacts whereby the second control circuit is disabled when the first control circuit is actuated to energize one of said relays and thereby open its normally closed contacts, power change sensing means, solenoids actuated by said power change sensing means to close both of said relays each time a power change occurs, and a switch connected in circuit with said motor to intermittently make and break the control circuits therefor.

10. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electric current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electric current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a reversible motor operatively connected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, a second control circuit including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture, a pair of relays each having a set of normally closed contacts connected in circuit with said second contacts and a set of normally closed contacts connected in circuit with said fourth contacts, the coils of said relays being connected in circuit, respectively, with said first set of contacts and said third set of contacts whereby the second control circuit is disabled when the first control circuit is actuated to energize one of said relays and thereby open its normally closed contacts, power change sensing means, solenoids actuated by said power change sensing means to close both sets of normally closed contacts each time a power change occurs, and a third solenoid actuated by said power change sensing means to operate said valve and enrich said fuel mixture while a power change is occurring.

11. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for providing an electric current representative of engine temperature, a solenoid operated by said electrical current to close a first set of contacts when the engine temperature is too high and to close a second set of contacts when the engine temperature is too low, means for providing a second electrical current representative of detonation in a cylinder of said engine, a solenoid operated by said second electric current to close a third set of contacts when detonation is occurring and to close a fourth set of contacts when no detonation is occurring, a reversible motor operatively connected to said valve, a control circuit actuated by said first and third contact sets to operate said motor and thereby enrich the fuel mixture, a second control circuits including said second and fourth sets of contacts for operating said motor to effect leaning out of said fuel mixture, a pair of relays each having a normally closed set of contacts connected in circuit with said second contacts and a normally closed set of contacts connected in circuit with said fourth contacts, the coils of said relays being connected in circuit, respectively, with said first set of contacts and said third set of contacts whereby the second control circuit is disabled when the first control circuit is actuated to energize one of said relays and thereby open its normally closed contacts, power change sensing means, solenoids actuated by said power change sensing means to close both sets of normally closed contacts each time a power change occurs, and a third solenoid actuated by said power change sensing means to momentarily operate said valve and enrich the fuel mixture when a normal power change occurs and to operate said valve continuously when the engine power is above or below a predetermined range.

12. A time delay switch unit comprising a polarized relay, a snap action switch actuated by the armature of said relay when a current of proper polarity is passed therethrough, a motor operated by said switch, a drum type switch coupled to said motor and including a set of contacts which is closed when the drum is moved a predetermined distance from a predetermined position, means urging said drum toward said predetermined position, and a solenoid actuated by closure of said contacts to move said snap action switch to open position.

13. In a fuel metering system, in combination, a valve for regulating the fuel-air ratio of a fuel mixture to be fed to an internal combustion engine, means for sensing detonation in a cylinder of said engine, means for sensing excessive or subnormal engine temperatures, and a control unit for said valve actuated by both of said sensing means for enriching said fuel mixture when necessary to prevent detonation or excessive engine temperatures, and for leaning out said fuel mixture responsive to subnormal engine temperatures or lack of detonation.

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