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[56]

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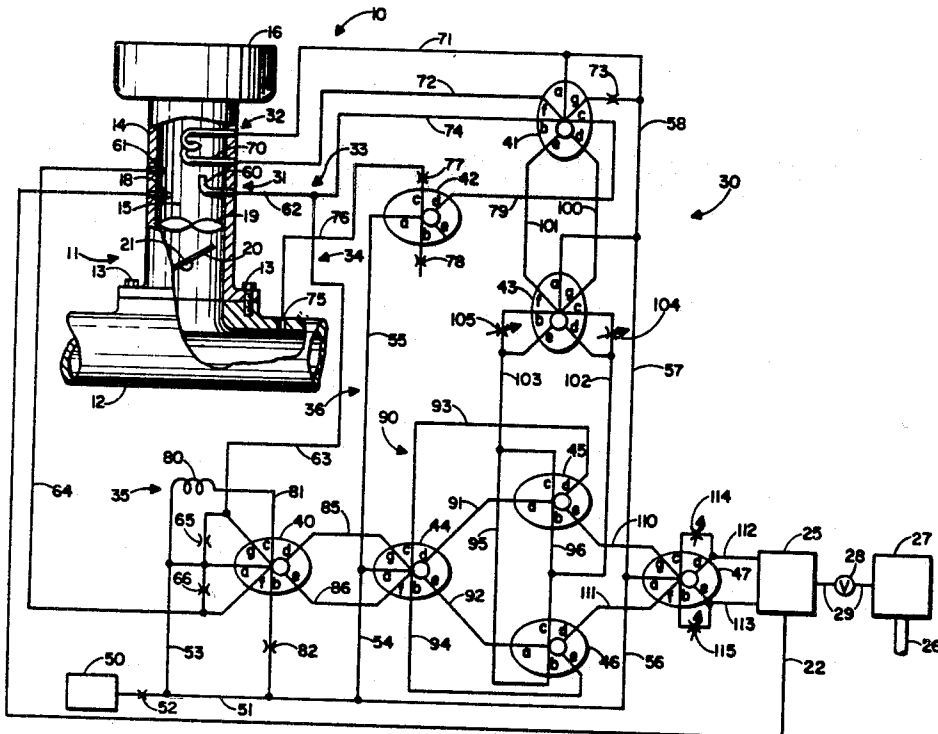
[54] CONTROL APPARATUS
10 Claims, 1 Drawing Fig.

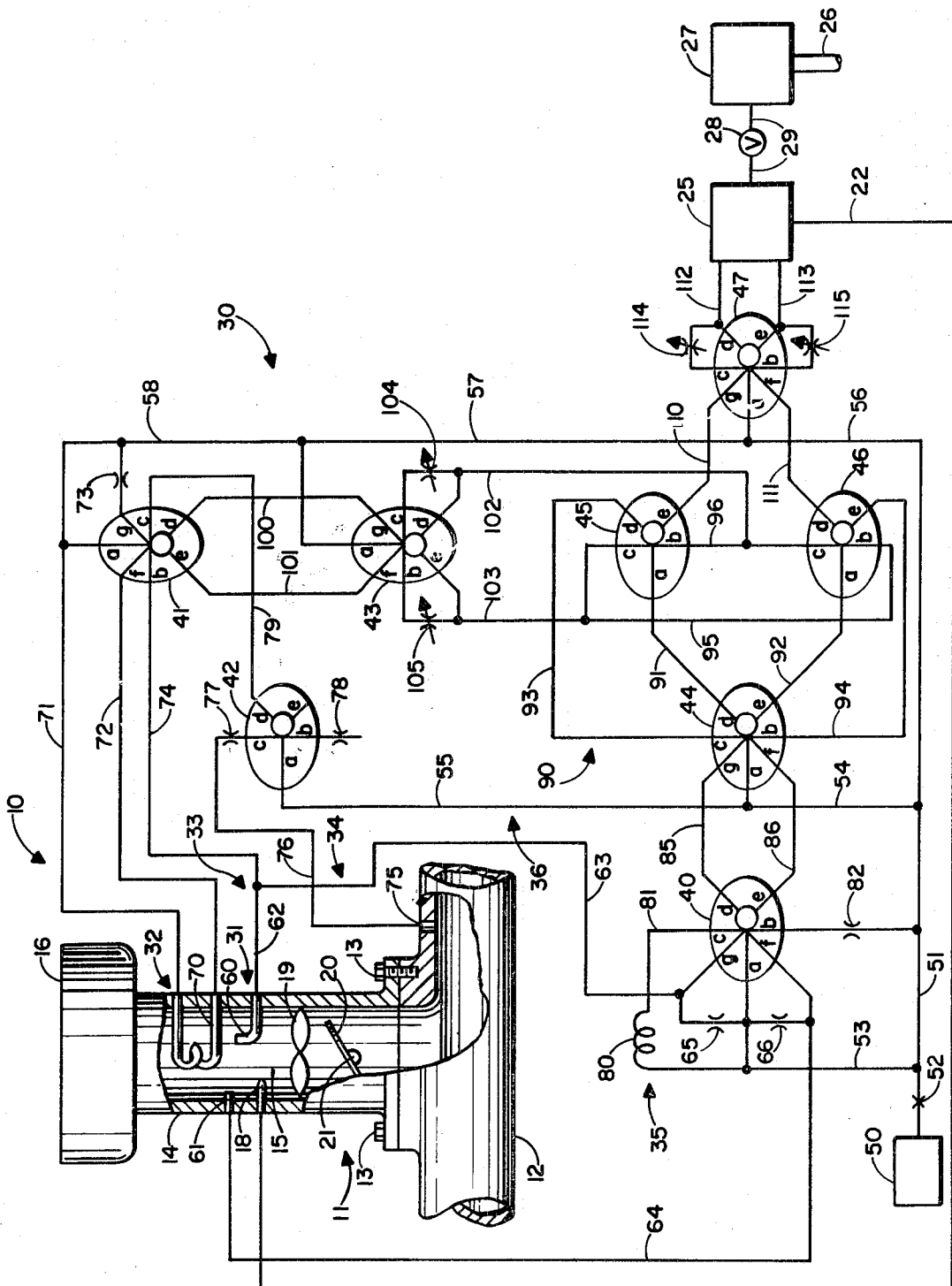
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ABSTRACT: A fluidic fuel control system wherein parameters including volumetric flow rate and temperature of air entering a mixing chamber are sensed and signals indicative thereof multiplied to provide a signal for controlling fuel flow into the mixing chamber.





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CONTROL APPARATUS

BACKGROUND OF THE INVENTION

This invention pertains generally to fuel control systems and more particularly to fluidic fuel control systems wherein fuel flow into a mixing chamber is controlled in response to mass air flow thereinto.

The operation of an internal combustion engine requires that the air and fuel be mixed in certain proportions before being supplied to the combustion chamber or chambers of the engine. In a reciprocating engine, the fuel to air ratio is normally controlled by means of a conventional carburetion system. This carburetion system basically comprises a mixing chamber and means for allowing the entry of fuel and air thereinto. The fuel-air mixture from the mixing chamber is supplied to the cylinder or cylinders of the engine by means of an intake manifold. A throttle valve is located between the mixing chamber and the manifold. Various auxiliary devices may be provided for controlling the starting fuel mixture and for controlling the fuel mixture under transient operating conditions.

In normal operation, both fuel and air are drawn into the mixing chamber by means of a partial vacuum which is transmitted thereinto from the intake manifold. A conventional carburetor controls primarily the volumetric fuel and air flows into the mixing chamber, whereas a proper fuel to air mixture requires control of the fuel and air mass flows into the mixing chamber. Since a conventional carburetor does not compensate for air temperature or air pressure, it cannot provide an optimum fuel to air mixture under many operating conditions.

The use of an improper fuel-air mixture in an internal combustion engine results in a number of detrimental effects. One of these is that optimum engine operation and efficiency cannot be achieved. Another is that noxious exhaust gases including excessive unburned combustion products are produced.

A further disadvantage of most conventional carburetors is that they contain a number of intricate moving mechanical parts including butterfly and needle valves, fuel floats, mechanical temperature sensors and complicated interconnecting linkages. The fact that all of these parts must be manufactured and assembled increases the cost and complexity of production. In addition, the working interrelationships of these mechanical parts is critical. Accordingly, the initial adjustments must be carefully performed. Further, since moving mechanical parts are included, they are subject to wear and the carburetor must be periodically readjusted.

Various of these problems have been at least partially overcome by fluidic fuel control systems in which at least certain of the parameters necessary to compute mass air flow into the mixing chamber are sensed fluidically. Further, in these systems, the fuel control signal is generally produced from computations which are carried out by means of fluidic elements. However, the only fluidic computation which has heretofore been utilized in these systems has been summation. Since air mass flow rate is given by the expression pV/Rt , where p is the air pressure, V is the volumetric flow rate, R is a constant and t is air temperature, it can be seen that a summation can give only an approximation to the air mass flow rate function. Further, this approximation is only good over limited ranges of values of the various parameters. It can also be seen that a fuel control system must include means for multiplying the various parameters necessary to compute air mass flow rate in order to produce a true air mass flow rate signal. Such a signal is required if a proper fuel to air mixture is to be provided.

Since prior art carburetion systems do not provide for multiplying signals indicative of any of the sensed parameters, they cannot provide an optimum fuel to air mixture for all operating conditions. Thus, it is apparent that these systems are not generally satisfactory for use with modern internal combustion engines.

SUMMARY OF THE INVENTION

The applicant's fuel control system comprises a mixing chamber in combination with an air intake passage and a fuel nozzle. Means is provided for sensing at least volumetric flow rate and temperature of the air entering the mixing chamber through the air intake passage. Signals indicative of the volumetric air flow rate and air temperature are multiplied to generate a signal indicative of mass air flow into the mixing chamber. This signal is supplied to a fuel-metering valve which controls the flow of fuel into the mixing chamber through the fuel nozzle. Means may also be provided for compensating for variations in air pressure. Additional means may be provided for sensing engine acceleration and loading and for sensing engine temperature. Signals indicative of the two last named parameters are utilized to improve transient engine operation.

In accordance with the teachings of this invention, the applicant's unique fluidic fuel control system provides accurate control over the fuel to air mixture supplied to the engine, thus improving engine efficiency and decreasing unburned combustion products in the engine exhaust gases. Automatic compensation is provided for variations in the volumetric air flow into the mixing chamber due to such factors as clogging of an air cleaner in the air intake passage. In addition, the applicant's invention makes maximum use of fluidic components in which there are no moving parts. Accordingly, wear is minimized and maximum reliability is achieved.

BRIEF DESCRIPTION OF THE DRAWING

The single figure of the drawing illustrates a preferred embodiment of the applicant's fluidic fuel control system showing a mixing chamber, an air intake passage partially broken away, and schematically showing fluidic sensors and logic circuit including a fluidic multiplier circuit.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the figure, reference numeral 10 generally designates fuel-air supply apparatus for a reciprocating internal combustion engine. Apparatus 10 includes fuel-mixing apparatus 11 which supplies a fuel mixture to an intake manifold 12. Fuel-mixing apparatus 11 is much simplified from a conventional carburetor in that it includes practically no moving parts or accessory devices. Fuel-mixing apparatus 11 is mounted on manifold 12 by means of a plurality of bolts 13. Manifold 12 distributes the fuel mixture to the cylinders of a conventional reciprocating engine (not shown).

Fuel-mixing apparatus 11 includes an air horn 14 through which air is drawn from the atmosphere into a mixing chamber 15. A conventional air cleaner 16 is provided at the inlet to air horn 14 to filter the air drawn therethrough.

Mixing apparatus 11 also includes a fuel nozzle 18 for injecting fuel into mixing chamber 15 wherein a turbulence generator 19 is provided for mixing fuel and air drawn thereinto. Turbulence generator 19 may comprise any device suitable for mixing fuel and air. It may, for example, comprise fixed vanes at the exit of mixing chamber 15 or it may be a moving element. A throttle valve 20 is provided at the base of mixing apparatus 11 so as to control the rate at which fuel mixture enters manifold 12. Throttle valve 20 is a butterfly valve which rotates about an offcenter pivot axis 21 such that the partial vacuum normally existing within manifold 12 tends to maintain it in a closed position.

Reference numeral 25 designates a fuel-metering valve which controls the fuel flow to fuel nozzle 18. Metering valve 25 is connected to be supplied with fuel from a fuel source (not shown) by means of a fuel line 26, a fuel pump 27, a shut off valve 28 and fuel lines 29. Fuel valve 25 is connected to fuel nozzle 18 by means of a fuel line 22. Fuel valve 25 may be of any suitable type wherein fuel flow is controlled in response to a differential pressure control signal supplied thereto. Many such devices are known in the prior art. One such suitable device is shown in the applicant's copending application Ser.

No. 721,994, filed Apr. 17, 1968, and assigned to the assignee of the present application. Additional devices, such as a vapor separator may be included in fuel lines 29 as desired. However, such devices are well known and will not be shown to simplify the drawing.

Reference numeral 30 generally designates fluidic control apparatus for controlling fuel valve 25. Control apparatus 30 includes an air flow velocity sensor 31, an air temperature sensor 32, an air pressure sensor 33, an engine demand sensor 34, an engine temperature sensor 35 and a fluidic computer circuit 36.

Computer circuit 36 comprises a plurality of fluid amplifiers designated by reference numerals 40—47. Amplifiers 40, 41 and 43—47 are proportional devices. Amplifier 42 may be either proportional or bistable. Each of these amplifiers includes a power nozzle "a", a first pair of opposing control ports "b" and "c", a first outlet passage "d" and a second outlet passage "e". In addition, amplifiers 40, 41, 43, 44 and 47 each include a second pair of opposing control ports "f" and "g". Reference hereinafter to a particular element of a fluid amplifier will be made by amplifier identification number and reference character of the particular element. For example, control port "b" of amplifier 40 will be indicated by "control port 40b".

Reference numeral 50 designates a source of filtered air which is connected to supply air to a conduit 51 through a valve 52. Power nozzles 40a—44a and 47a are connected to conduit 51 by means of conduits 53—58.

The velocity sensor 31 comprises a total pressure probe 60 and a static pressure probe 61 in communication with the passage through air horn 14. Total pressure probe 60 is connected to control port 40g by means of conduits 62 and 63. Static pressure probe 61 is connected to control port 40f by means of conduit 64. Conduits 63 and 64 are connected to conduit 51 through conduit 53 and orifices 65 and 66.

Air temperature sensor 32 comprises a capillary passage 70 located within air horn 14. One end of capillary passage 70 is connected to conduit 51 through conduits 56, 57, 58 and 71. The other end of capillary passage 70 is connected to control port 41f through a conduit 72. Control port 41g is connected to conduit 58 through an orifice 73 which also comprises a portion of air temperature sensor 32.

Air pressure sensor 33 includes total pressure probe 60. Total pressure probe 60 is connected to control port 41b through conduits 62 and 74.

Engine demand sensor 34 comprises a pressure port 75 in communication with the interior of manifold 12. Pressure port 75 is connected to control port 42c through a conduit 76 and an orifice 77. Control port 42b is vented to the atmosphere through an orifice 78. Outlet passage 42d is connected to control port 41c through a conduit 79. Outlet passage 42e is vented to the atmosphere.

Engine temperature sensor 35 comprises a capillary passage 80 in thermal communication with the engine (not shown). One end of capillary passage 80 is connected to conduit 51 through conduit 53. The other end of capillary passage 80 is connected to control port 40c through a conduit 81. Control port 40b is connected to conduit 51 through an orifice 82 which also comprises a portion of engine temperature sensor 35.

Outlet passages 40d and 40e are connected to control ports 44g and 44f through conduits 85 and 86. Control ports 44g and 44f comprise a first input to a fluidic multiplier circuit 90 which includes amplifiers 44, 45 and 46 and interconnecting conduits 91—96. Conduits 95 and 96 comprise a second input to multiplier circuit 90. Conduits 95 and 96 are connected to amplifier 41 through amplifier 43. Specifically, outlet passages 41d and 41e are connected to control ports 43g and 43f through conduits 100 and 101. Outlet passages 43d and 43e are connected to conduits 96 and 95 through conduits 102 and 103. Amplifier 43 is provided with negative feedback paths through variable orifices 104 and 105.

Multiplier circuit 90 may be of any suitable type capable of producing an output signal which is the product of input signals supplied thereto. However, the circuit shown in the figure is the subject of U.S. Pat. application Ser. No. 659,964 filed Aug. 11, 1967 in the name of Charles W. Rainer, now U.S. Pat. No. 3,499,440 and assigned to the assignee of the present application. Fluidic multiplier circuit 90 is fully described in the above-identified application. No additional description is necessary.

Outlet passages 45e and 46d comprise the output of multiplier circuit 90. Outlet passages 45e and 46d are connected to control ports 47g and 47f through conduits 110 and 111. Outlet passages 47d and 47e are connected to the control input of fuel valve 25 through conduits 112 and 113. Amplifier 47 is provided with negative feedback paths through variable orifices 114 and 115.

In normal operation of the engine with which fuel supply apparatus 10 is associated, the action of the pistons and valves within the engine causes a partial vacuum in intake manifold 12. The reduced pressure within manifold 12 functions to draw fuel mixture from mixing chamber 15 at a rate depending on the position of throttle valve 20 and the pressure differential thereacross. The removal of fuel mixture from mixing chamber 15, in turn, results in air flow through air horn 14. In order to maintain the proper fuel to air mass ratio in mixing chamber 15, fuel flow into chamber 15 is controlled in response to mass air flow therinto. The applicant's fluidic fuel control system functions to control fuel flow into mixing chamber 15 in response to mass air flow therinto as follows. As a prerequisite to operation of the applicant's fuel control system, filtered air under pressure must be provided to power the fluid amplifiers and certain of the sensors. In addition, fuel under pressure must be supplied to fuel-metering valve 25. Air under pressure may be supplied by means of a compressor operating as an engine accessory. Likewise, fuel under pressure may be provided by means of a fuel pump operating as an engine accessory.

During engine start up, engine power is not available. However, since the air and fuel pressure required to power fluidic control apparatus 30 and supply fuel under pressure to fuel valve 25 is not substantial, cranking the engine during the starting process will provide sufficient air and fuel pressure to start the engine. In addition, the fuel valve 25 may be constructed such that in the absence of any control signals, it will allow a predetermined flow of fuel therethrough sufficient to start the engine. A temperature controlled mechanical choke may be provided for limiting the air flow through air horn 14 so as to enrich the fuel mixture and to provide for easy engine starting.

With source 50 in operation and valve 52 open, air under pressure is supplied directly to power nozzles 40a—44a and 47a, thereby causing fluid streams to issue therefrom. In addition, as described in previously mentioned application Ser. No. 659,964, air in varying amounts is supplied to power nozzles 45a and 46a from outlet passages 44d and 44e. The operation of amplifiers 40—47 is identical. Therefore, only the operation of amplifier 40 will be discussed in detail. In the absence of pressure differential signals supplied to the control ports of amplifier 40, the fluid stream issuing from power nozzle 40a will be substantially equally divided between outlet passages 40d and 40e. Accordingly, in the absence of pressure differential input signals to amplifier 40, no pressure differential output signals will be produced thereby. However, if a pressure differential input signal is supplied to either or both pairs of opposing control ports, a pressure differential output signal will generally be produced between outlet passages 40d and 40e. If a pressure differential signal is supplied to the first pair of opposing control ports such that the pressure at control port 40b is greater than the pressure at control port 40c, the pressure produced in outlet passage 40d will be greater than the pressure produced in outlet passage 40e. Similarly if a pressure differential signal is supplied to the second pair of opposing control ports such that the pressure at control port 40f

is greater than the pressure at control port 40g, the pressure produced in outlet passage 40d will be greater than the pressure produced in outlet passage 40e.

Air velocity sensor 31 operates to produce a pressure differential signal indicative of the velocity of air flow through air horn 14 as follows. Air under pressure is supplied to total pressure probe 60 through conduit 53, orifice 65, conduit 63 and conduit 62. Air under pressure is also supplied to static pressure probe 61 through conduit 53, orifice 66 and conduit 64. Thus, air flows out of probes 60 and 61 into air horn 14.

The rate at which air flows from probes 60 and 61 is dependent on the pressures present at the respective probes. The pressure at total pressure probe 60 is independent of air flow velocity through air horn 14. The pressure at static pressure probe 61 varies inversely with air flow velocity through air horn 14. Thus, the differential in flow rates from probes 60 and 61, and consequently the pressures produced in conduits 63 and 64, varies with flow velocity through air horn 14. Specifically, as the flow velocity through air horn 14 increases, the pressure in conduit 63 increases with respect to the pressure in conduit 64. Since the cross-sectional area of air horn 14 is fixed, the pressure differential between conduits 63 and 64 is also indicative of the volumetric rate of air flow into mixing chamber 15.

The pressure signals in conduits 63 and 64 are supplied to one pair of control ports of amplifier 40. Amplifier 40 is also supplied with a pressure differential signal indicative of engine temperature from engine temperature sensor 35.

In order to understand the operation of engine temperature sensor 35 and air temperature sensor 32, it is necessary to know the effects of temperature on air flow through a simple orifice and through a capillary passage. Air flow through a simple orifice is substantially independent of temperature over the range of temperatures to which a fuel control system for an engine would normally be exposed. However, over the same range of temperatures, impedance to air flow through a capillary passage is directly dependent upon the viscosity of the air which, in turn, is directly dependent upon the air temperature. Accordingly, as the temperature of the air flowing through a capillary passage increases, pressure drop across the passage increases and air flow through the passage decreases. These characteristics of air flow through an orifice and a capillary passage are utilized in the applicant's fuel control system.

Control port 40c is supplied with a fluid pressure signal from conduit 51 through conduit 53, capillary passage 80 and conduit 81. Capillary passage 80 is in thermal communication with the engine (not shown). Heat is transferred from the engine to the air within capillary passage 80 such that the temperature of the air there within approximates the temperature of the engine. Thus, as the temperature of the engine increases, the pressure drop across capillary passage 80 increases and the pressure signal supplied to control port 40c decreases.

A pressure signal is also supplied to control port 40b, which opposes control port 40c, from conduit 51 through orifice 82. Since the impedance produced by orifice 82 to air flow therethrough is substantially of temperature, the pressure signal supplied to control port 40c varies primarily only with changes in pressure supplied thereto from conduit 51. The pressure supplied to capillary passage 80 from conduit 51 varies in the same manner as the pressure supplied to orifice 82. Accordingly, the pressure differential signals supplied to control ports 40b and 40c is indicative of only the temperature of the engine. Further, as the temperature of the engine increases, the pressure signal supplied to control 40c decreases with respect to the pressure at control 40b. Capillary passage 80 and orifice 82 are sized such that for a predetermined normal engine temperature, the pressure signals supplied to control ports 40b and 40c are substantially equal.

Amplifier 40 functions to sum the pressure signals supplied to control ports 40 b, 40c, 40f and 40g. From the previous discussion of amplifier 40, it can be seen that as the volumetric rate of air flow into mixing chamber 15 increases, the pressure

signal produced in outlet passage 40e increases relative to the pressure signal produced in outlet passage 40d. As the engine temperature increases, the pressure signal produced in outlet passage 40e decreases relative to the pressure signal produced in outlet passage 40d.

The pressure signals produced in outlet passages 40d and 40e are transmitted to control ports 44g and 44f through conduits 85 and 86. As indicated hereinbefore, control ports 44g and 44f comprise a first input to fluidic multiplier circuit 90. Conduits 95 and 96 comprise a second input to fluidic multiplier circuit 90. Conduits 95 and 96 are supplied with pressure signals from amplifier 43 as will now be described.

A pressure differential signal indicative of the temperature of the air entering mixing chamber 15 is supplied to control ports 41f and 41g from air temperature sensor 32 as follows. Air temperature sensor 32 comprises capillary passage 70 which is located within air horn 14. Control port 41f is supplied with a pressure signal from conduit 51 through conduits 56, 57, 58 and 71, capillary passage 70 and conduit 72. A pressure signal is also supplied to control port 41g from conduit 51 through conduits 56, 57 and 58 and orifice 73. Capillary passage 70 operates in the same manner as capillary passage 80 to decrease the pressure at control port 41f as the temperature of the air entering the mixing chamber 15 increases. The pressure drop across orifice 73 is substantially independent of temperature. Therefore, as the temperature of the air entering mixing chamber 15 increases, the pressure at control port 41f decreases with respect to the pressure at control port 41g. Since the operation of capillary passage 70 is identical to the operation of capillary passage 80, no further description will be provided.

Control port 41b is supplied with a pressure signal indicative of the pressure of air entering the mixing chamber 15. This signal is supplied by conduit 62 which comprises a portion of air pressure sensor 33. Control port 41c, which opposes control port 41b, receives a pressure signal indicative of engine and/or loading from amplifier 42 as follows.

As previously pointed out, operation of the engine with which intake manifold 12 is associated results in a partial vacuum within the manifold. For steady state operation the pressure within manifold 12 remains constant at some value dependent on the operating conditions of the engine. However, if an increase load is placed on the engine, the engine will decelerate. Slowing down of engine operation results in a decrease in the partial vacuum within manifold 12 or an increase in pressure therein. Similarly, if it is desired to accelerate the engine, throttle valve 20 is opened. Opening of throttle valve 20 results in a decrease in the partial vacuum within manifold 12 or an increase in pressure therein. Conversely, either a decrease in the load on the engine or closing of throttle valve 20 results in a decrease in pressure within manifold 12. Accordingly, any change in the setting of throttle valve 20 or in the loading condition of the engine (hereinafter referred to as engine demand) results in a change in pressure within manifold 12. Changes in engine demand are reflected as pressure changes at pressure port 75.

For improved transient engine operation, it has been found advantageous to increase the fuel to air ratio when engine acceleration is desired or an increased load is placed on the engine. This is accomplished by transmitting the pressure signal from pressure port 75 to control port 42c through conduit 76 and orifice 77. Control port 42b, which opposes control port 42c is vented to the atmosphere through orifice 78. The signal produced at outlet passage 42d is transmitted to control port 41c through conduit 79. Orifices 77 and 78 are sized such that for normal engine demand conditions and normal pressure of the air entering mixing chamber 15, equal pressures are supplied to control ports 41b and 41c.

Amplifier 41 functions to sum the air temperature, air pressure and engine demand signals and produce a pressure differential output signal between outlet passages 41d and 41e indicative of this summation. Specifically, the pressure produced in outlet passage 41e increases with respect to the

pressure produced in outlet passage 41d if the air temperature increases, the air pressure decreases, and/or engine demand decreases. The output signal of amplifier 41 is transmitted to control ports 43f and 43g through conduits 101 and 100. Control ports 43b and 43c are provided with negative feedback signals through variable orifices 105 and 104. Variable orifices 105 and 104 provide for varying the gain of amplifier 43. The signal produced by amplifier 43 is transmitted through conduits 103 and 102 to conduits 95 and 96 which comprise the second input to multiplier circuit 90. Variable orifices 105 and 104 thus provide for varying the relative magnitudes of the signals supplied to the first and second inputs of multiplier circuit 90.

Fluidic multiplier circuit 90 produces a pressure differential output signal indicative of the product of the signals supplied to the first and second inputs thereof. The output signal of multiplier circuit 90 is produced between outlet passages 45e and 46d. The operation of multiplier circuit 90 is fully described in patent application Ser. No. 659,964. Reference may be made to that application for a complete operational description.

Since the signal supplied to the first input of multiplier circuit 90 is a function of the volumetric rate of air flow into mixing chamber 15 and the signal supplied to the second input is a function of the temperature of the air entering mixing chamber 15, it can be seen that the output signal of the multiplier circuit is a function of the product of volumetric flow rate and temperature of the air entering the mixing chamber. The output signal of fluidic multiplier circuit 90 can thus provide a much closer indication of mass rate of air flow into mixing chamber 15 than can be provided by prior art systems.

The output signal from multiplier circuit 90 is supplied to amplifier 47 which is provided with negative feedback signals through variable orifices 114 and 115. The negative feedback paths provide means for varying the gain of amplifier 47. The output signal from amplifier 47 can thus be tailored to the signal requirements of fuel valve 25. The output signal of amplifier 47 comprises the output signal of multiplier circuit 90 modified by the gain of amplifier 47. The output signal of amplifier 47 thus also provides an indication of the mass air flow into mixing chamber 15. Since fuel flow into mixing chamber 15 from fuel valve 25 is controlled by this signal, it is apparent that the applicant's present fuel control system provides much closer control over the mass fuel to air ratio in mixing chamber 15 than can be provided by prior art systems.

I claim:

1. In combination with fuel mixing apparatus including a mixing chamber having an air intake passage and a fuel nozzle for introducing air and fuel thereto, the improvement which comprises:

air velocity sensing means operable to produce a fluid signal indicative of air flow velocity through the air intake passage;

air temperature sensing means operable to produce a fluid signal indicative of air temperature in the air intake passage;

a fluidic multiplier circuit having first, a second, and third proportional fluid amplifiers each comprising a power nozzle for issuing a fluid stream, a pair of outlet passages for receiving portions of the fluid stream, and a plurality of control ports for directing the fluid stream toward the outlet passages, said proportional fluid amplifiers connected so that the outlet passages of said first proportional fluid amplifier supply fluid to the power nozzles of said second and third proportional fluid amplifiers, said fluidic multiplier circuit further having first and second inputs connected to the control ports of the proportional fluid amplifiers and an output connected to outlet passages of said second and third proportional fluid amplifiers, said fluidic multiplier circuit operable to produce an output signal indicative of the product of the signals supplied to the first and second inputs thereof;

means connecting said air velocity sensing means to the first input of said fluidic multiplier circuit;

means connecting said air temperature sensing means to the second input of said fluidic multiplier circuit;

fuel control means operable to control fuel flow to the fuel nozzle of said fuel mixing apparatus in response to an input signal; and

means connecting the output of said fluidic multiplier circuit to said fuel control means.

2. The apparatus of claim 1 further including air pressure-sensing means operable to produce a fluid signal indicative of air pressure in the air intake passage and means connecting said air pressure sensing means to the second input of said fluidic multiplier circuit.

3. The apparatus of claim 1 in combination with an internal combustion engine and further including demand-sensing means operable to produce a fluid signal indicative of engine acceleration and loading and means connecting said demand-sensing means to an input of said fluidic multiplier circuit.

4. The apparatus of claim 3 further including engine temperature sensing means operable to produce a fluid signal indicative of engine temperature and means connecting said engine temperature-sensing means to an input of said fluidic multiplier circuit.

5. The apparatus of claim 4 wherein said means connecting said engine temperature-sensing means to an input of said fluidic multiplier circuit comprises means for summing the fluid signal indicative of engine temperature and the fluid signal indicative of air flow velocity through the air intake passage.

6. In combination with fuel-mixing apparatus of the type wherein signals indicative of a plurality of parameters of air entering a mixing chamber are combined to produce a signal indicative of air mass flow thereto and wherein fuel flow into the mixing region is controlled in response to the air mass flow signal, the improvement which comprises:

air velocity sensing means operable to produce a first fluid signal indicative of the volumetric rate of flow of air into the mixing chamber;

air temperature sensing means operable to produce a second fluid signal indicative of the temperature of air entering the mixing chamber; and

fluidic multiplier means including a plurality of proportional fluid amplifiers each comprising a power nozzle for issuing a fluid stream, a pair of outlet passages for receiving portions of the fluid stream, and control port means for directing the fluid stream toward the outlet passages, said air velocity sensing means and said air temperature sensing means connected to said control port means so that a third fluid signal indicative of a product of the first and second fluid signals is produced, said third fluid signal for controlling fuel flow into the mixing chamber.

7. The apparatus of claim 6 further including air pressure sensing means operable to produce a fourth fluid signal indicative of the pressure of air entering the mixing chamber and means connecting said air pressure sensing means to said fluidic multiplier means, said third fluid signal further being a function of the pressure of air entering the mixing chamber.

8. The apparatus of claim 7 in combination with an internal combustion engine and further including demand sensing means operable to produce a fifth fluid signal indicative of engine acceleration and loading and means connecting said demand-sensing means to said fluidic multiplier means, said third fluid signal further being a function of engine acceleration and loading.

9. The apparatus of claim 8 further including engine temperature-sensing means operable to produce a sixth fluid signal indicative of engine temperature and means connecting said engine temperature-sensing means to said fluidic multiplier means, said third fluid signal further being a function of engine acceleration and loading.

10. The apparatus of claim 9 wherein:

said air velocity sensing means includes a total pressure probe and a static pressure probe operable to produce signals indicative of the total pressure and static pressure of air entering the mixing region; and

said air temperature sensing means comprises a capillary passage located in the air entering the mixing chamber

and means for supplying fluid under pressure to one end of the capillary passage.

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