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Sweeney

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[45] **July 17, 1973**

[54] **CARBURETOR APPARATUS AND METHOD**

[75] Inventor: **Maxwell Patrick Sweeney,** Los Angeles, Calif.

[73] Assignee: **Energy Transmission Corporation,** San Bernardino, Calif.

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[21] Appl. No.: **93,133**

[52] **U.S. Cl.**..... **123/119 R,** 123/119 E, 123/119 F, 123/124 R, 261/50 A

[51] **Int. Cl.** **F02m 9/06,** F02m 7/24, F02m 7/10

[58] **Field of Search**..... 123/124 R, 124 A, 123/124 B, 119 R, 119 F, 119 E; 261/50 A

[56] **References Cited**

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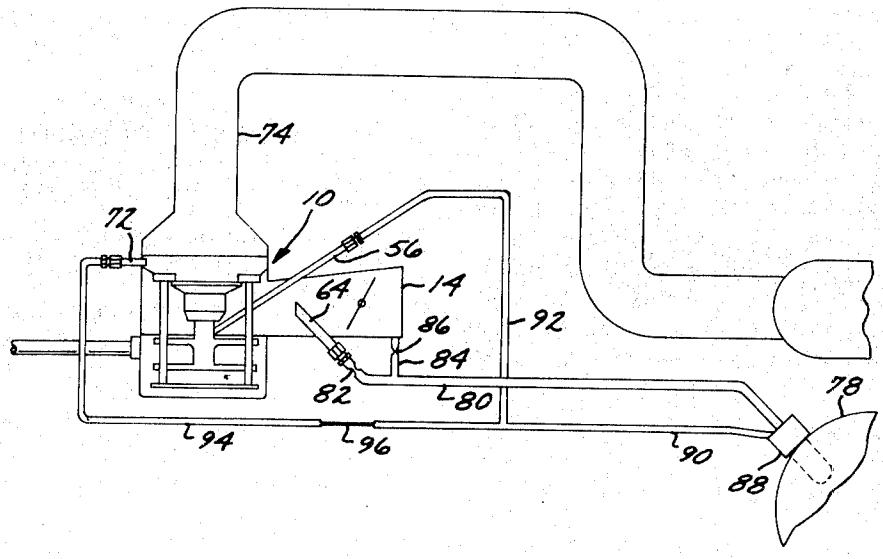
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Primary Examiner—Wendell E. Burns
Attorney—Albert L. Gabriel

[57] **ABSTRACT**

Apparatus and method for reducing pollutant emissions by improving fuel atomization and optimizing air-fuel ratio in the carburetion of internal combustion engines. A small stream of bleed air is mixed with the fuel after it has passed through the fuel metering restriction but before atomization thereof, and then this mixture of fuel and bleed air is passed through the atomizing orifice. The atomizing velocity is thereby increased, causing improved atomization and hence better combustion of the mixture, resulting in less pollutant emissions. By providing the bleed air from a source wherein the pressure is generally inversely related to the rate of fuel flow, a relatively large amount of bleed air is made available to thus improve combustion at low speed operating conditions when hydrocarbon emissions tend to be excessive, while accommodating greater fuel flow as required during high speed operating modes when atomization is normally good. Modulation of this bleed air flow provides an effective means for adjusting the air-fuel ratio output of the carburetor. Thus, in one form of the invention temperature-responsive bleed air modulation provides self-adjustment to compensate for the natural tendency of a carburetor to richen the mixture as its ambient temperature increases. In another form of the invention the air-fuel ratio is automatically adjusted to compensate for air-fuel ratio deviations from the desired average by sensing the air-fuel ratio and modulating the bleed air flow in response thereto.

30 Claims, 12 Drawing Figures



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SHEET 1 OF 3

FIG.1

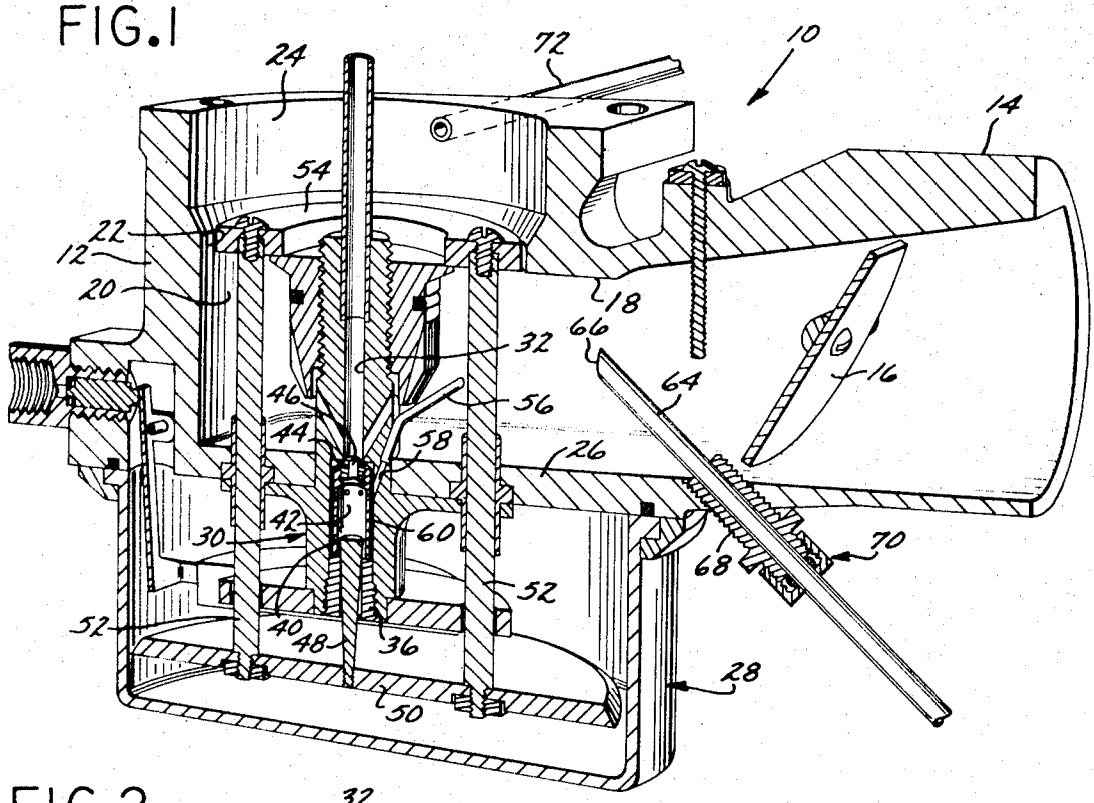


FIG.2

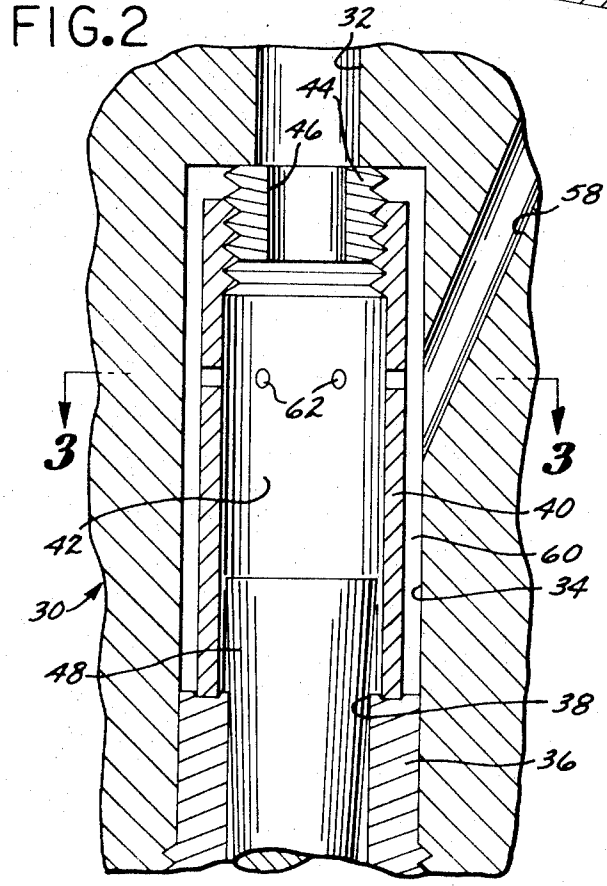
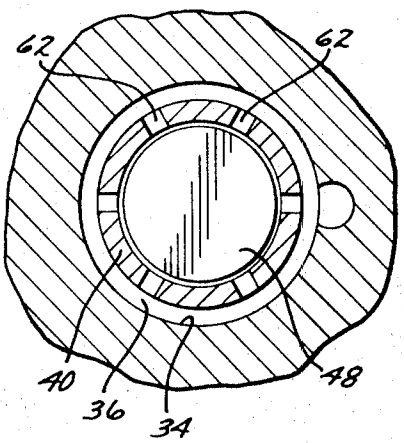


FIG.3



INVENTOR.
MAXWELL PATRICK SWEENEY
BY
ATTORNEY

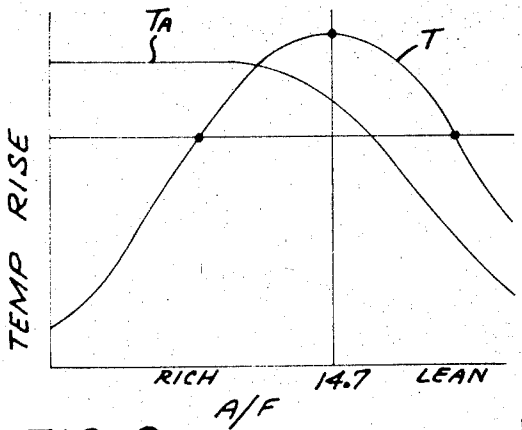


FIG.6

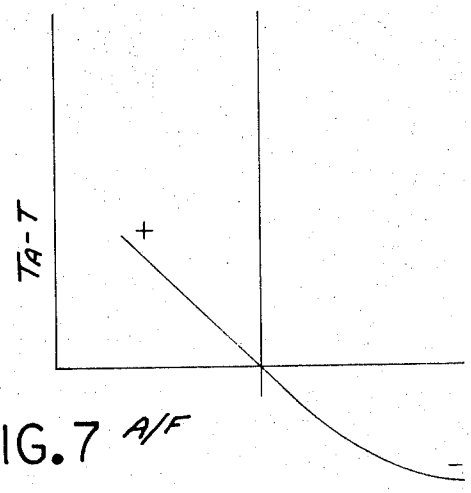


FIG.7

FIG.4

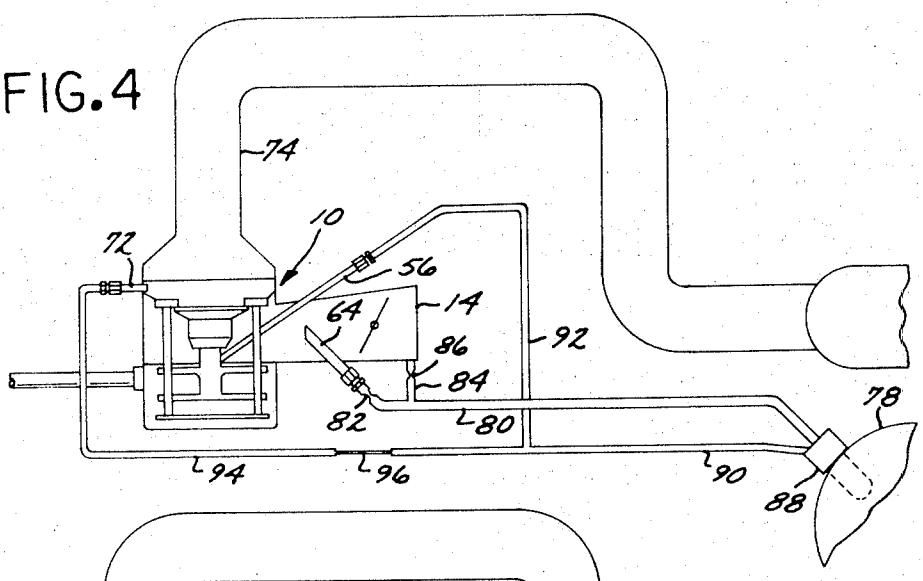
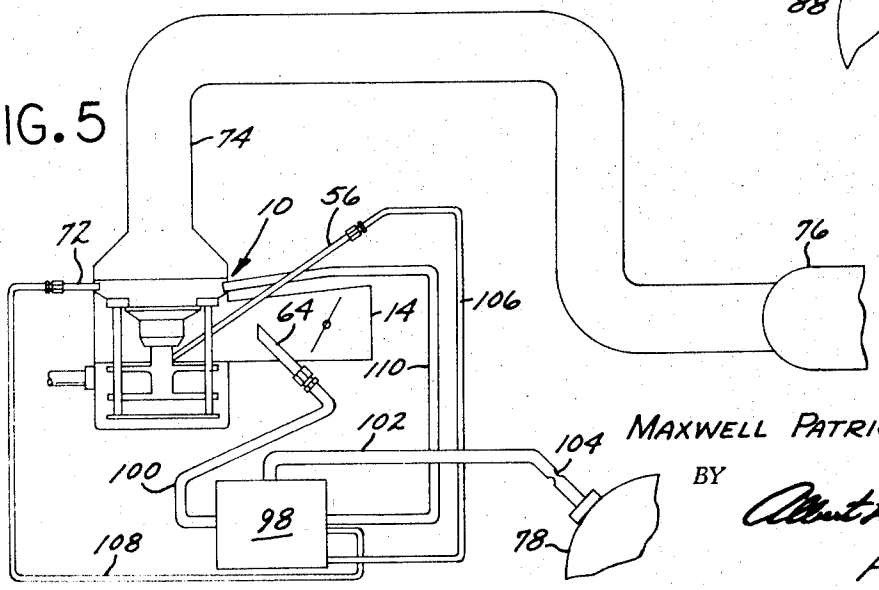


FIG.5



INVENTOR.
MAXWELL PATRICK SWEENEY
BY
ATTORNEY

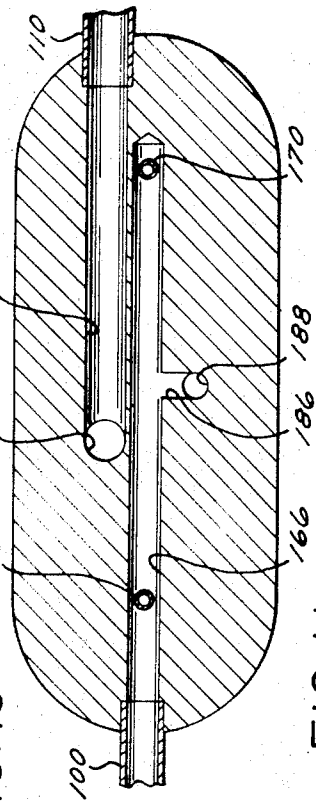


FIG. 10

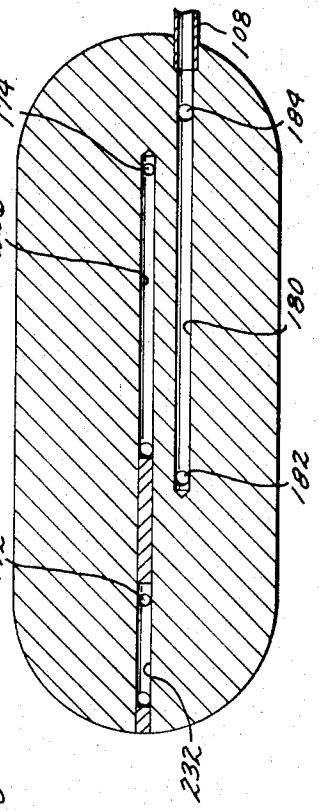


FIG. 11

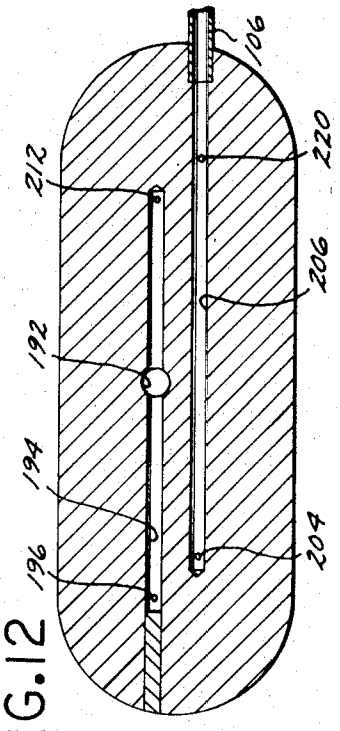


FIG. 12

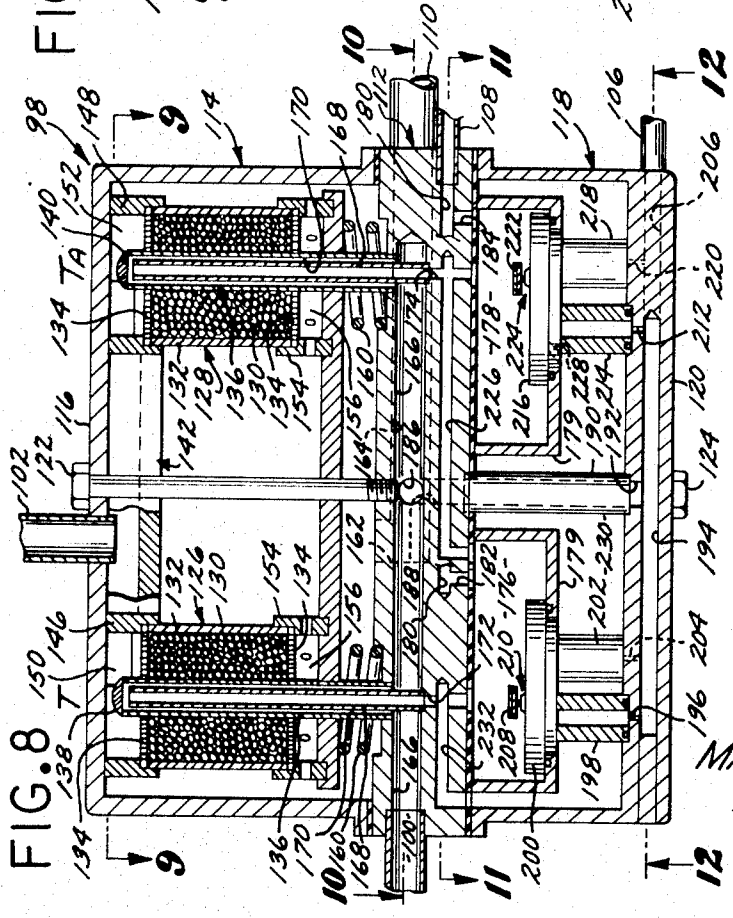


FIG. 8

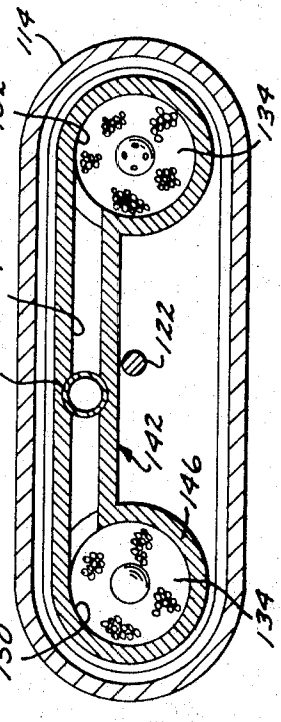


FIG. 9

INVENTOR.
MAXWELL PATRICK SWEENEY
BY
ATTORNEY

CARBURETOR APPARATUS AND METHOD

BACKGROUND OF THE INVENTION

According to practice, carburetion means employed for supplying mixtures of fuel and air to internal combustion engines function as "dead reckoning" devices which are intended to supply a fixed schedule of fuel in relation to airflow to an engine. Such dead reckoning carburetion is generally intended to provide what is considered to be an optimum schedule of carburetion, as for example to supply a nearly constant air-fuel ratio at about 16-to-1 for maximum economy during cruise modes of operation, somewhat richer mixtures at idle or near idle, and mixtures near optimum for maximum power at about 13-to-1 for wide-open throttle modes.

However, the intended schedule of carburetion is seldom achieved in practice, resulting in less than optimum performance, economy, and drivability, and perhaps even more important today, resulting in unacceptable quantities of pollutant emissions. Even under the best of operating conditions and with new equipment that is in good working order, the present dead reckoning carburetion means is generally incapable of accurately following the carburetion schedule for a particular engine design. However, as the engine and its parts wear, as various deposits are accumulated in the engine, and particularly as such deposits cause fouling of fuel metering parts, of the crankcase blowby valve, and even of the throttle itself, and also if the engine is tuned up by mechanics of varying skills, the conventional carburetion means tends to deviate further and further from the optimum schedule of carburetion.

Additionally, further important deviations from the desired optimum schedule of carburetion are caused by such continually varying factors as fuel temperature, ambient temperature, atmospheric humidity, barometric pressure, and altitude. While some of these effects may be crudely allowed for by additional dead reckoning means added to already complex carburetor devices, such as automatic choke means to schedule richer mixtures during start-up and engine warm-up, for the most part carburetor devices are incapable of properly compensating for such variations in each individual operating situation and condition.

This whole problem has been greatly compounded by the increasingly stringent requirements to reduce pollutant emissions from internal combustion engines, for the reason that emissions are greatly affected by even small deviations from optimum carburetion. The principal undesirable exhaust emissions are hydrocarbons, carbon monoxide, and oxides of nitrogen. Relatively minor variations in carburetion can greatly affect each one of these undesired exhaust emissions.

The effects of variations in carburetion on the final pollutant emissions from a vehicle are even more pronounced in systems which employ a catalytic converter in the exhaust pipe to treat the exhaust before it issues to the atmosphere, and wherein it is desired that the converter function on exhaust gas only. Without air being added to the exhaust gas, a catalytic converter will effect a major reduction in hydrocarbons and carbon monoxide only if the average exhaust corresponds to an air-fuel ratio which is relatively lean. On the other hand, known catalytic conversion of oxides of nitrogen will occur to a major extent only when the exhaust corresponds to an air-fuel ratio which is relatively rich. Thus, in internal combustion engine systems employing catalytic exhaust conversion of this type, it is critical that a particular schedule of carburetion be accurately followed.

Despite the foregoing problems, it is known in the art that there exists a very small region of average air-fuel ratios between which it is possible to simultaneously minimize all three of these types of pollutant emissions, so that they will be very substantially reduced as compared with the emissions from engines embodying present dead reckoning carburetion devices. However, this range of air-fuel ratios is so narrow that each of the effects on carburetion referred to above will, in the absence of effective compensation means to keep the air-fuel ratio within this range, be a very substantial factor in causing the emission control of one or more of these three types of pollutants to be greatly diminished.

Another serious problem in the art is that fuel atomization, an important factor in efficient combustion and hence in pollution control, is poorest in conventional carburetor devices during the operating modes that generally produce the highest hydrocarbon emissions, and hence in which good atomization is most important. The degree of atomization is generally proportional to the square of velocity at the fuel atomizing orifice. However, in conventional carburetor devices, the velocity at the fuel atomizing orifice is generally linearly proportional to the rate of fuel flow, so that atomization in the conventional carburetor is generally very poor in the low speed operating modes of from idle to about **30** miles per hour cruise; yet it is in these low speed operating modes that the highest hydrocarbon emissions are produced.

SUMMARY OF THE INVENTION

In view of these and other problems in the art, it is an object of the present invention to provide a novel carburetion method and apparatus for internal combustion engines wherein pollutant emissions are reduced by improving fuel atomization, particularly in the low speed operating modes during which hydrocarbon emissions normally tend to be unduly high.

Another object of the invention is to provide a novel apparatus and method for maintaining the average schedule of carburetion of a carburetor within desired narrow limits. In this connection, it is an object to provide a novel carburetion apparatus and method of the character described for automatically adjusting the air-fuel ratio to a substantially optimum value wherein hydrocarbon, carbon monoxide, and nitrogen oxide emissions are minimized, the adjustment automatically compensating for such cumulative factors tending to vary the air-fuel ratio as engine wear, deposits, and the like, and also for such transient factors tending to vary the air-fuel ratio as fuel temperature, ambient temperature, atmospheric humidity, barometric pressure, altitude, and the like.

Another object of the invention is to provide novel means of the character described whereby a carburetor can be changed from a dead reckoning device to an automatically self-adjusting mechanism.

A further object of the invention is to provide a novel apparatus and method of the character described for refining carburetion towards its optimum during starting and engine warmup conditions.

A still further object of the invention is to provide a novel method and apparatus for modulating the fuel flow in relation to airflow in internal combustion en-

gine carburetors which is particularly simple and inexpensive, yet which is accurately controllable and is highly sensitive due to amplification of the effects thereof in the carburetor.

According to the present invention a small stream of bleed air is mixed with the fuel after it has passed through the normal fuel metering restriction, but before the fuel has been atomized, and then this mixture of fuel and bleed air is passed through the atomizing orifice. The increased volume of the mixture causes a substantial increase in the atomizing velocity, and since atomization is dependent upon the square of velocity, there will be a great improvement in atomization, resulting in better combustion and less pollutant emissions. Preferably, the bleed air is provided from a source wherein the pressure is generally inversely related to the rate of fuel flow, as for example from a tube opening in the downstream direction in the carburetor choke throat. By this means, a relatively large amount of bleed air is provided to thus improve combustion at low speed operating conditions when hydrocarbon emissions tend to be excessive, while a relatively small amount of bleed air is provided during high speed operating modes when greater fuel flow must be accommodated, but when atomization is normally good.

The small stream of bleed air mixed with the fuel between the fuel metering restriction and the atomizing orifice not only provides a means for better atomization of the fuel, but also provides a means, by the modulation thereof, for adjusting the air fuel ratio to the engine. The carburetor acts as an amplifier of this modulation, whereby a small change in the airflow of this stream causes a major change in the air fuel ratio provided by the carburetor to the engine. Thus, a small amount of bleed air at this critical point in the carburetor provides a large amount of control leverage for adjustment of the air-fuel ratio, thereby providing an effective means for automatic control of the air-fuel ratio to compensate for the factors tending to vary it, so as to provide very close to an optimum schedule of carburetion for any particular carburetor.

According to one form of the invention, the small stream of bleed air is modulated by temperature-responsive means to increase the bleed airflow and thereby tend to lean the mixture in response to an increase in the ambient temperature, for self-adjustment to compensate for the natural tendency of the carburetor to richen the mixture as its ambient temperature increases.

According to another form of the invention, the air-fuel ratio is automatically adjusted to compensate at least in part for air-fuel ratio deviations from the desired average by sensing the air-fuel ratio and modulating the bleed airflow in response thereto. Such sensing of the air-fuel ratio is accomplished according to the invention by sensing a temperature differential between two oxidation reactions of exhaust samples which are identical except for the addition of air to one of them. As the mixture richens, the reaction with the added air tends to get relatively hotter, while as the mixture leans, the reaction with the added air tends to get relatively colder. Temperature-responsive valve means is actuated in response to the temperature differential between these two oxidation reactions to modulate the flow of bleed air so as to compensate for any tendency for the mixture to become either too lean or too rich. This valve means is also responsive to ambient temperature during cold start and warm-up conditions to further modulate the bleed air for proper carburetor adjustment during these conditions.

Further objects and advantages of the present invention will appear during the course of the following part of the specification, wherein the details of construction, mode of operation, and novel method steps of presently preferred embodiments are described with reference to the accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view, in vertical section, illustrating a carburetor which has been modified for the provision of bleed air thereto in accordance with the present invention.

FIG. 2 is a greatly enlarged, fragmentary vertical section particularly illustrating the bleed air mixing chamber, with the fuel metering restriction below it and the fuel atomizing orifice above it, and the passage means for introducing the bleed air into the mixing chamber.

FIG. 3 is a horizontal section taken on the line 3—3 in FIG. 2.

FIG. 4 is a diagrammatic view illustrating one form of the invention wherein the bleed airflow is modulated in response to ambient temperature changes for self-adjustment of the carburetor to compensate for the natural tendency thereof to richen the mixture as its ambient temperature increases.

FIG. 5 is a diagrammatic view illustrating another form of the invention wherein the air-fuel ratio is automatically adjusted to compensate for air-fuel ratio deviations from the desired average by sensing the air-fuel ratio and modulating the bleed airflow to the carburetor in response thereto.

FIG. 6 is a graph plotting temperature rise against air-fuel ratio for the oxidation reactions of two exhaust samples, showing two curves, one for the exhaust sample without added air (T) and the other for the exhaust sample with added air (T_a).

FIG. 7 is a graph plotting the differential between curves T_a and T of FIG. 6 against air-fuel ratio, the temperature difference T_a minus T illustrated in FIG. 7 providing an indication of the richness or leanness of the mixture, and a useful signal for actuating temperature-responsive valve means in the form of the invention shown in FIG. 5 to compensate for air-fuel ratio deviations from the desired average.

FIG. 8 is a vertical section, with portions in elevation, illustrating the bleed air modulating means employed in the form of the invention shown in FIG. 5, this means including a pair of catalyst beds for oxidizing exhaust samples with and without added air to develop the T_a minus T temperature differential indication of air-fuel ratio, and also including temperature differantial responsive valve means for modulating the flow of bleed air in response to this temperature differential signal T_a minus T.

FIG. 9 is a horizontal section taken on the line 9—9 in FIG. 8.

FIG. 10 is a horizontal section taken on the line 10—10 in FIG. 8.

FIG. 11 is a horizontal section taken on the line 11—11 in FIG. 8.

FIG. 12 is a horizontal section taken on the line 12—12 in FIG. 8.

DETAILED DESCRIPTION

Referring to the drawings, and at first particularly to FIGS. 1, 2, and 3 thereof, these figures illustrate a carburetor 10 which has the present invention applied thereto. For illustrative purposes an "air valve" type carburetor is illustrated in FIGS. 1 to 3. However, it is to be understood that the principles of the present invention are applicable to any type of carburetor.

The carburetor 10 includes a body 12 having a laterally extending intake conduit 14 with a choke valve 16 pivotally mounted therein. The intake conduit 14 communicates through a choke throat 18 downstream of choke valve 16 with air chamber 20 defined within the main part of body 12. The air chamber 20 communicates at its upper end through air valve seat 22 with outlet conduit 24. The bottom of air chamber 20 is defined by a generally horizontal wall 26 which forms the bottom of the body 12. A fuel bowl 28 is in peripherally sealed relationship with the bottom wall 26 of body 12, extending downwardly therefrom. Fuel is admitted to bowl 28, and the bowl 28 is vented, by conventional means (not shown).

The carburetor 10 includes a tubular core structure 30 that is mounted on the bottom wall 26 of the body. Core structure 30 is generally vertically oriented, extending both down into the fuel bowl 28 and upwardly through the center of air chamber 20. The tubular core structure 30 has a vertical, axial bore 32 extending therethrough, with a counterbore 34 extending upwardly from the lower end of core structure 30 to a position proximate the wall 26.

A tubular plug 36 is threadedly mounted in the lower end portion of the counterbore 34, and defines the fuel metering orifice 38. A cylindrical mixing chamber sleeve 40 extends upwardly from the upper end of plug 36 within the counterbore 34, the mixing chamber sleeve 40 being coaxially arranged within the counterbore 34 and defining therein a mixing chamber 42 within which bleed air and fuel are mixed according to the present invention. This mixing chamber 42 functions both as an air controlled fuel valve and as a means for increasing the fuel flow velocity without increasing the rate of flow of the fuel portion of the mixture. An atomizing plug 44 is threadedly mounted in the upper end portion of mixing chamber sleeve 40, the plug 44 defining atomizing orifice 46 at the upper end of the mixing chamber 42.

A tapered fuel metering pin 48 is connected at its lower end, which is the small end thereof, to a horizontal plate 50 in the fuel bowl 28. Metering pin 48 extends upwardly through the plug 36 and cooperates with the fuel metering orifice 38 to control the rate of fuel flow from the bowl 28 into the fuel mixing chamber 42. Plate 50 is connected through a plurality of vertical rods 52 with air valve 54 which cooperates with the air valve seat 22, the rods 52 sliding through suitable bushings in the wall 26.

The bleed air of the present invention is furnished through a bleed air inlet tube 56 extending through the wall of the carburetor body 12. Inlet tube 56 communicates with a bleed air inlet passage 58 which extends through the tubular core structure 30 and opens into an annulus 60 defined between the wall of counterbore 34 and the outer cylindrical surface of mixing chamber sleeve 40. The bleed air which is thus furnished through inlet tube 56 and passage 58 to the annulus 60 passes through a series of holes 62 in the wall of the mixing chamber sleeve 40 into mixing chamber 42 wherein the bleed air is mixed with the fuel which has entered mixing chamber 42 through the fuel metering orifice 38.

One of the important advantages obtained by mixing the bleed air with the fuel in mixing chamber 42 is that for a given rate of fuel flow, the effective volume of the fuel will be increased according to the volume of the added air, and hence the fuel velocity through the atomizing orifice 46 will be correspondingly increased. Since the degree of atomization is dependent upon the square of velocity through the atomizing orifice, the addition of the bleed air in the critical region of the mixing chamber between the fuel metering orifice and the atomizing orifice will provide a great deal of improvement in the atomization of the fuel, with a corresponding improvement in the efficiency with which the fuel is burned in the engine, and a reduction in pollutant emissions.

In conventional carburetors the atomization is generally poor in the low speed operating modes, as for example between idle and about 30 miles per hour cruise, as the velocity at the atomizing orifice in conventional carburetors is generally linearly related to the fuel flow rate, which is then low. However, such low speed operating modes produce the highest hydrocarbon emissions, and are thus the conditions in which it is desirable to have the best fuel atomization for improved burning efficiency in the engine.

According to the present invention, an increased flow of bleed air is provided to the mixing chamber 42 during such low speed operating modes so as to greatly improve the fuel atomization when it is thus most desirable, and the flow of bleed air to the mixing chamber 42 is reduced during high speed operating modes when the atomization is normally good so as to accommodate the greater amount of fuel flow then required. A presently preferred means for providing this increase of bleed air during low speed operating modes and decrease thereof during high speed operation is to furnish the bleed air from a source wherein the pressure is generally inversely related to the rate of fuel flow. One satisfactory source of bleed air having these characteristics is a bleed air pick-up tube 64 which has an open intake end 66 thereof located within the choke throat 18 and directed downstream. Thus, when the rate of fuel flow is relatively low, as for example during the low speed operating modes, the rate of air flow through the carburetor intake throat 18 is relatively low, and the pressure at the intake end 66 of the bleed air pick-up tube 64 is relatively high. Conversely, at high speed operating modes, when the rate of fuel flow is relatively high, the air flow through the carburetor intake throat 18 will be high, and the pressure at the intake end 66 of the bleed air pick-up tube 64 will be relatively low.

The bleed air pick-up tube 64 extends from its said open intake end 66 through the wall of the carburetor intake conduit 14, being supported in a suitable mounting sleeve 68 and packing gland 70, and connects with the bleed air inlet tube 56 so as to furnish the bleed air to the mixing chamber 42.

FIGS. 4 and 5 of the drawings show the carburetor 10 that is described hereinabove and is illustrated in FIGS. 1 to 3 in combination with an internal combustion engine which includes as parts thereof an air-fuel intake conduit 74 that is connected to the carburetor outlet conduit 24 and leads to an engine intake manifold 76.

The engine also includes an exhaust manifold **78.** FIGS. **4** and **5** illustrate two different methods, and corresponding apparatus for accomplishing such methods, for modulating the bleed air flow to the carburetor **10** for self-adjustment of the air-fuel ratio provided by the carburetor to the engine. FIG. **4** diagrammatically illustrates a form of the invention wherein the bleed airflow is modulated in response to ambient temperature changes for self-adjustment of the carburetor so as to compensate for the natural tendency thereof to richen the mixture as its ambient temperature increases. FIG. **5** diagrammatically illustrates another form of the invention wherein the air-fuel ratio is self-adjusted to compensate for air-fuel ratio deviations from the desired average by sensing the air-fuel ratio and modulating the bleed airflow to the carburetor to bring the air-fuel ratio back to the desired narrow range thereof for optimum carburetion.

The air-fuel ratio adjustment accomplished by the respective methods and apparatus of FIGS. **4** and **5** is in addition to the improved atomization of the fuel and consequent reduction in pollutant emissions, which is still present as described in detail hereinabove in connection with FIGS. **1** to **3.** Additionally, by providing the bleed air source in the embodiments of the invention shown in FIGS. **4** and **5** in the same manner as the bleed air is provided in FIG. **1,** i.e., by a downstream opening pick-up tube located in the carburetor intake throat, the effect of greater increase in vaporization at idle and low speed operating modes when it is more necessary is preserved.

The carburetor acts as an amplifier of any modulation of the bleed air flow to the mixing chamber **42,** so that it requires only a small change in the bleed air flow to mixing chamber **42** to effect a major change in the air-fuel ratio provided by the carburetor to the engine. Thus, control of the air-fuel ratio of the carburetor by modulation of the bleed air flow to mixing chamber **42** provides a high degree of sensitivity or control leverage, whereby methods and apparatus such as those illustrated in FIGS. **4** and **5** are enabled to precisely compensate for variations in the air-fuel ratio.

The actual adjustment of air-fuel ratio as the result of an increase or decrease in bleed air provided to the mixing chamber **42** operates as follows: the greater the rate of flow of bleed air into the mixing chamber **42,** the greater the pressure drop in atomizing orifice **46** and hence the pressure in mixing chamber **42** relative to the pressures in other parts of the carburetor, and hence the less the pressure drop across the fuel metering orifice **38,** resulting in a reduction of the rate of fuel flow for a given amount of primary airflow through the carburetor. Conversely, a reduction in the rate of flow of bleed air into the mixing chamber **42** causes a relative reduction of the pressure in chamber **42,** thereby increasing the pressure drop across the fuel metering orifice **38,** and causing an increase in the rate of fuel flow relative to the primary airflow rate through the carburetor. Accordingly, an increase in bleed airflow into the mixing chamber **42** causes an increase in the air-fuel ratio, or a leaning of the mixture, while a decrease in the rate of bleed airflow into the mixing chamber **42** causes a decrease in the air-fuel ratio or a richening of the mixture.

This relationship of increased bleed air leaning the mixture and decreased bleed air richening the mixture holds true except as the bleed airflow approaches zero, in which case the weight of the fuel column tends to become too high and to actually result in a decrease of fuel flow and a leaning of the mixture. Accordingly, it is preferred in practicing the present invention to always provide a minimum flow of bleed air to the mixing chamber **42** so that the invention will always be functioning in a range wherein an increase in signal air will lean the mixture and a decrease in signal air will richen the mixture, so that the air-fuel ratio change will always be predictable in response to modulation of the bleed airflow.

The method and apparatus illustrated in FIG. **4** requires no moving parts to be added to the carburetor to provide compensation for the natural tendency of a carburetor to richen as its ambient temperature increases. Factors tending to cause the mixture to richen as ambient temperature increases include a decrease in fuel viscosity allowing a greater rate of fuel flow, and in the case of air valve type carburetor there is greater lift on the air valve, lifting the fuel metering pin and further opening the fuel metering orifice.

Referring now particularly to FIG. **4,** the bleed air pick-up tube **64** connects with a bleed air supply tube **80** having an orifice **82** therein. This orifice **82** renders the basic flow of bleed air through the supply tube **80** generally independent of ambient temperature changes, since the rate of flow of the mass of air therethrough varies only inversely as the square root of the absolute temperature. A bypass line **84** connects the bleed air supply tube to the intake conduit **14** upstream of the choke valve, bypass line **84** also having an orifice **86** therein. This bypass line **84** prevents fuel from backing up in the bleed air lines during closed choke starting.

The bleed air supply tube **80** connects to an air stove **88** associated with the engine exhaust manifold **78** which heats the bleed air to a temperature corresponding to engine operating temperature. The bleed air then passes through a heated air line **80,** and thence through the signal air tube **92** to the bleed air inlet tube **56** which conducts the bleed air into the carburetor to be mixed with the fuel in the mixing chamber **42.** However, a vent air tube **94** vents some of the bleed air from the heated air line **90** through the vent air return tube **72.** This vent air tube **94** has a capillary tube section **96** therein, and the mass of airflow through such a capillary tube section varies approximately inversely as the absolute temperature to the 3/2 power. Thus as the temperature of the bleed air increases in response to an increase in engine temperature, there will be a decrease in the mass of airflow through the capillary tube section **96,** and hence less bleed air vented and more bleed air will flow through the signal air tube **92** to mix with the fuel in the mixing chamber **42.** Accordingly, the added bleed air mixed with the fuel as engine temperature increases will lean the mixture, thereby tending to compensate for the natural tendency of the carburetor to richen with increase in engine temperature. Nevertheless, even without the capillary vent, heating of the bleed air causes increased flow thereof by thermal expansion, and causes some fuel vaporization, both effects tending to lean the mixture.

Referring now to FIG. **5,** this figure diagrammatically illustrates the employment of valve mechanism **98** which modulates the flow of bleed air to the mixing chamber **42** in response to air-fuel ratio deviations from the desired average so as to compensate for such

deviations and tend to bring the air-fuel ratio back to the desired average. The valve mechanism **98** receives bleed air from the bleed air pick-up tube **64** through bleed air supply tube **100.** The valve mechanism **98** functions in response to changes in the amount of combustible ingredients in the engine exhaust gases, which reflects changes in the richness of the mixture provided by the carburetor to the engine. Accordingly, a continuous sample of engine exhaust gases is provided from the exhaust manifold **78** through an exhaust gas supply tube **102** to the valve mechanism **98.** The exhaust gas supply tube **102** has an orifice **104** therein which limits the rate of flow of exhaust gases to the valve mechanism **98.**

The bleed air modulating valve mechanism **98** provides the modulated bleed air through signal air tube **106** to the bleed air inlet tube **56** which provides the bleed air to the carburetor mixing chamber **42.** Part of the bleed air that was furnished to the valve mechanism **98** through the supply tube **100** is vented from the valve mechanism **98** through vent tube **108** to the vent air return tube **72.** The spent exhaust gases from the valve mechanism **98** are vented back to the carburetor outlet conduit **24** through exhaust gas vent tube **110.**

FIGS. **6** and **7** graphically illustrate the manner in which the amount of combustible ingredients in the exhaust gases is utilized according to the present invention to provide a signal in the modulating valve mechanism **98** that reflects the state of the air-fuel ratio from the carburetor. The exhaust gases from the exhaust gas supply tube **102** are divided into two substantially identical exhaust gas samples. A small amount of air is added to one of these samples, and then the two exhaust samples are subjected to separate substantially identical oxidation reactions, which may be accomplished by catalytic reaction means, afterburner means, or other oxidizing means. FIG. **6** plots temperature rise against the air-fuel ratio for each of these two separate oxidation reactions, the curve T being for the oxidation reaction without added air, and the curve T_a being for the oxidation reaction with added air. The 14.7 air-fuel ratio line is approximately stoichiometric.

As the mixture richens, and the amount of combustible ingredients accordingly increases in the exhaust gases, the sample with added air tends to get relatively hot because of more combustion, while the sample without added air tends to get relatively cold because of less combustion (a shortage of residual oxygen). On the other hand, as the mixture leans, the sample with added air tends to get relatively cold, and the sample without added air tends to get relatively hot. Accordingly, the T_a curve is offset to the left or in the rich direction from the T curve in FIG. **6.**

FIG. **7** is a plot of the temperature difference between the Ta and the T curves of FIG. **6,** this temperature difference being plotted against the air-fuel ratio. FIG. **7** graphically illustrates the T_a minus T signal which is utilized in the modulating valve mechanism **98** to adjust the bleed air flow to compensate at least in part for air-fuel ratio deviations from the desired average air-fuel ratio. The valve mechanism **98** can be set to respond to any value of T_a minus T as shown in the curve in FIG. **7,** so as to tend to adjust the carburetor to any desired air-fuel ratio.

Reference will now be made to FIGS. **8** to **12** which illustrate a presently preferred valve mechanism **98** for developing the differential temperature signal T_a minus T and for modulating the bleed airflow in response thereto.

The valve mechanism **98** includes a central, generally horizontal plate **112** which has upper and lower housing sections secured to opposite sides thereof. Thus, extending upwardly from the central plate **112** is an upper housing section **114** having a top wall **116,** and extending downwardly from the central plate **112** is a lower housing section **118** which includes a bottom plate **120.** The upper and lower housing sections **114** and **118** are secured to the central plate **112** by respective bolts **122** and **124,** or by other suitable means.

A pair of substantially identical catalyst chambers **126** and **128** are defined within opposite sides of the upper housing section **114,** and contain substantially identical quantities of the same catalyst material **130.** The catalyst chambers **126** and **128** are defined by a pair of generally vertically oriented cylinders **132** disposed in opposite sides of upper housing section **114,** each of the cylinders **132** having perforated end plates **134** at its upper and lower ends. Tubes **136** extend coaxially through the respective cylinders **132,** extending through suitable openings in the perforated end plates **134.** Thus, the actual catalyst chambers **126** and **128** are each defined radially between the respective cylinder **132** and tube **136,** and axially between the spaced perforated end caps **134.** The tube **136** of the left-hand catalyst chamber **126** is provided with a solid cap **138,** while the tube **136** of the right-hand catalyst chamber **128** is provided with a perforated cap **140** which allows a small amount of bleed air to mix with the exhaust gas sample that will pass through the catalyst chamber **128** as described hereinafter more in detail.

The exhaust inlet structure is generally designated **142,** and is disposed in the upper part of the upper housing section **114.** This exhaust inlet structure **142** includes a divider passage **144** which is adapted to receive the flow of exhaust gas from exhaust gas supply tube **102** that passes through the top wall **116** of upper housing section **114,** the divider passage **144** dividing this exhaust gas flow into two substantially equal exhaust gas samples. The divider passage **144** leads to a pair of substantially identical circular casings **146** and **148** which define respective exhaust inlet plenum chambers **150** and **152** which are coaxially arranged above the respective catalyst chambers **126** and **128.** Thus, substantially equal exhaust gas samples are provided from opposite ends of the divider passage **144** to the exhaust inlet plenum chambers **150** and **152,** and thence downwardly through the respective catalyst chambers **126** and **128** in which the exhaust gases are subjected to substantially equal beds of the catalyst material **130.**

A pair of perforated rings **154** define substantially identical exhaust outlet plenums **156** below the respective catalyst chambers **126** and **128,** the bottom of these exhaust outlet plenums **156** being defined by a generally horizontal plate **158** which is biased upwardly into its seated position by a pair of coil springs **160,** the plate **158** thus serving to secure the various parts of the exhaust gas sampling system together in the upper housing section **114.**

The exhaust gases from the exhaust outlet plenums **156** pass out of the upper housing section **114** through an exhaust outlet hole **162** and passage **164** in the central plate **112,** and thence out of the valve mechanism

98 through the exhaust gas vent tube 110 connected to the right-hand side of the central plate 112.

The bleed air supply tube 100 communicates with a bleed air inlet passage 166 in the central plate 112. A pair of substantially identical small tubes 168 are supported in the central plate 112 so as to extend upwardly across the bleed air inlet passage 166 and coaxially through most of the lengths of the respective tubes 136, terminating short of the respective tube caps 138 and 140. An annulus 170 is defined between each of the outer tubes 136 and its respective inner tube 168, each of these annuli 170 communicating at its lower end with the air inlet passage 166 to receive thermal sensing air from the inlet passage 166. Accordingly, thermal sensing air from the bleed air inlet passage 166 passes through the center of each of the catalyst chambers 126 and 128 through a passage which includes the respective annulus 170 and then the respective inner tube 168. Since the cap 138 associated with the left-hand catalyst chamber 126 is solid, the exhaust gas sample passing into the left-hand catalyst chamber 126 through the respective exhaust inlet plenum chamber 150 will have no air added thereto. However, since the cap 140 associated with the right-hand catalyst chamber 128 is perforated, a small amount of the thermal sensing air which has passed upwardly through the respective annulus 170 is enabled to pass into the respective exhaust inlet plenum chamber 152 and mix with the exhaust gas sample that passes through the catalyst chamber 128. Accordingly, the exhaust gas samples passing through the catalyst chambers 126 and 128 are respectively the T and T_a samples.

The thermal sensing air from the inner tubes 168 passes downwardly through respective passages 172 and 174 into respective left and right-hand temperature sensing chambers 176 and 178 which are defined within respective inner housing structures 179 in the upper part of lower housing section 118. This flow of thermal sensing air from the inner tubes 168 through the respective passages 172 and 174 and thence into the respective temperature sensing chambers 176 and 178 will have a major effect in determining the temperatures within the respective sensing chambers 176 and 178.

A vent air accumulation passage 180 extends through the central plate 112 into communication with air vent tube 108 which connects to the central plate 112 at its right-hand side. This vent air accumulation passage 180 communicates with the temperature sensing chambers 176 and 178 through respective outlet passages 182 and 184, whereby the thermal sensing air that was provided to the chambers 176 and 178 is vented from these chambers along with other flows of bleed air into the chambers as hereinafter described.

Part of the bleed air entering the valve mechanism 98 through supply tube 100 and inlet passage 166 is conducted from passage 166 through a transverse passage 186 and thence downwardly through a passage 188, tube 190, and hole 192 into a divider passage 194 disposed within the bottom plate 120 of the lower housing section 118. Part of this bleed air is permitted to pass from the left-hand end portion of the divider passage 194 upwardly through an orifice 196 and tube 198 into a subchamber housing 200 that is located in the left-hand temperature sensing chamber 176. From the subchamber housing 200 this bleed air is enabled to flow downwardly out through another bleed air tube 202 and thence downwardly through an orifice 204 into a signal air accumulation passage 206 in the bottom plate 120, the accumulation passage communicating with the signal air tube 106 at the right-hand side of the bottom plate 120.

A bimetal thermoelement 208 is located in the left-hand temperature sensing chamber 176, and controls a valve 210 in the subchamber housing 200. When the valve 210 is fully closed, the entire flow of bleed air which is admitted through orifice 196 and tube 198 into the subchamber housing 200 will pass out of the housing 200 through tube 202 and orifice 204 into the signal air accumulation passage 206 thereby becoming a part of the signal air flow. However, as the valve 210 opens, it allows part of this signal air flow to bleed out of the subchamber housing into the temperature sensing chamber 176, and thence to be vented out through the outlet passage 182 and vent air accumulation passage 180, thereby reducing the flow of signal air.

Part of the bleed air from the divider passage 194 will flow upwardly from the right-hand end portion thereof through an orifice 212 and a tube 114 into a subchamber housing 216 located in the right-hand temperature sensing chamber 178. Part of the bleed air from this subchamber housing 216 will pass downwardly and outwardly therefrom through a bleed air tube 218 and an orifice 220 into the signal air accumulation passage 206 to become part of the signal air flow in the signal air tube 106. A bimetal thermoelement 222 is located in the right-hand temperature sensing chamber 178 controls a valve 224 in the subchamber housing 216. As the valve 224 tends to close, it will cause an increase in the flow of bleed air from the subchamber housing 216 out through bleed air tube 218 and orifice 220 into the signal air accumulation passage 206; while opening of the valve 224 reduces such flow of signal air by venting more bleed air from the subchamber housing 216 into the right-hand temperature sensing chamber 178, such vented bleed air escaping from chamber 178 through outlet passage 184 into the vent air accumulation passage 180.

The valves 210 and 224 are set to operate in their range of maximum sensitivity, which is on the order of about one-half open, at a predetermined average temperature for normal engine operating conditions. The valve 210 is arranged so that it tends to open with an increase in the temperature within sensing chamber 176, and tends to close with a decrease in temperature in the sensing chamber 176. Conversely, the valve 224 is arranged so that it tends to close with an increase in temperature in the sensing chamber 178, and tends to open with a decrease in the temperature in sensing chamber 178.

If the mixture becomes leaner, the temperature in the left-hand sensing chamber 176 (T) tends to increase, and the temperature in the right-hand sensing chamber 178 (T_a) tends to decrease. The temperature increase in the left-hand chamber 176 causes its valve 210 to open further, thus venting more of the bleed air from subchamber housing 200, reducing the flow of bleed air to the signal air accumulation passage 206, tending to richen the mixture. At the same time, the decrease in temperature in sensing chamber 178 tends to open its valve 224 to vent bleed air from subchamber housing 216, and further reduce the flow of bleed air into the signal air accumulation passage 206, further tending to richen the mixture. Accordingly, if the mixture tends to

become leaner, the response of the two valves **210** and **224** is cumulative to increase the amount of bleed air that is vented, and to thereby decrease the flow of signal air to the signal air tube **106** to cause the mixture to richen.

Conversely, if the mixture becomes richer, the temperature in the left-hand sensing chamber **176** (T) tends to decrease, and the temperature in the right-hand sensing chamber **178** (T_a) tends to increase. This causes the valve **210** in the left-hand chamber **176** to tend to close, reducing the amount of bleed air which it vents from subchamber housing **200,** increasing the amount of bleed air which flows from the subchamber housing **200** to the signal air accumulation passage **206.** At the same time, this also causes valve **224** in the right-hand sensing chamber **178** to tend to close, reducing the amount of bleed air which it vents from subchamber housing **116,** increasing the amount of bleed air which flows from the subchamber housing **216** to the signal air accumulation passage **206.** The valves **210** and **224** thus again operate cumulatively, to cause an increase in the flow of signal air to the signal air tube **106,** thereby tending to lean the mixture.

Summarizing this normal operation of the modulating valve mechanism **98** to compensate for changes in the fuel-air ratio, if the mixture becomes too lean, the left side becomes hotter and the right side becomes colder, so both valves tend to open and vent more air, allowing less bleed air to go to the mixing chamber **42** so as to richen the mixture; while if the mixture becomes too rich, the right side becomes hotter and the left side colder, so both valves tend to close and vent less air, resulting in more bleed air being furnished to the mixing chamber **42** to lean the mixture.

This normal operation of the modulating valve mechanism **98** involves actuation in response to the T_a minus T differential temperature signal. However, if the ambient temperature increases so that the entire valve mechanism **98** becomes hotter, the left-hand valve **210** tends to open further and the right-hand valve **224** tends to close further, so that the effect is for the valves to cancel each other out. Similarly, if the entire valve mechanism becomes colder, the left-hand valve **210** tends to close, while the right-hand valve **224** tends to open, and again the effect is that the valves tend to cancel each other out. However, this automatic compensation for ambient temperature changes, or overall temperature changes in the valve mechanism **98,** is only effective in the normal temperature operating range, and does not operate during cold start and warmup conditions. Thus, the left-hand valve **210** is set so that it is normally closed for cold start conditions, and remains closed until the ambient temperature has reached a certain predetermined value above which the normal differential signal operation of the valve mechanism **98** is desired. However, while the left-hand valve **210** is thus closed during the cold start and warmup conditions, the right-hand valve **224** remains operative, being furthest open during the cold start condition, and gradually closing as the temperature increases during warmup.

The valve mechanism **98** functions as a mixture enrichening device as desired under cold start and warmup conditions in the following manner: during the cold start condition, the entire valve mechanism **98** is cold, and accordingly the left-hand valve **210** is completely closed, and the right-hand valve **224** is substantially completely open. At this time the catalyst beds are relatively cold, being heated relatively slowly, and are not effective as catalytic converters. The open right-hand valve **224** provides a free vent passage which permits venting of substantially all of the bleed air from subchamber housing **216,** so that substantially no bleed air will be provided from subchamber housing **216** to the signal air accumulation passage **206.** With the left-hand valve **210** completely closed, none of the bleed air is vented from the corresponding subchamber housing **200,** such bleed air passing out of the housing **200** into the signal air accumulation passage **206.** However, because of the substantially completely open right-hand valve **224,** at least part of such bleed air can back up through the right-hand orifice **220** and tube **218** and subchamber housing **216** and also be vented out through the valve **224.** The net result is that the signal air provided to the signal air tube **106** is at a minimum level during the cold start condition, thereby enrichening the mixture as required.

During the warmup phase of operation in which the left-hand valve **210** remains closed, the right-hand valve **224** will gradually close from the substantially completely open position which it had at cold start. This gradual closing of the right-hand valve **224** gradually reduces the amount of bleed air allowed to vent therethrough, thereby gradually increasing the amount of signal air allowed to flow out of the valve mechanism through the the signal air tube **106,** and in this manner the mixture will be gradually leaned through the warmup interval, as required. Then, at a predetermined temperature the left-hand valve **210** will start opening so as to vent some of the bleed air from the left-hand subchamber housing **200,** so that the mixture will not continue to leaned in direct response to the continued gradual closing of the right-hand valve **224,** and from this point on, when the catalyst chambers are hot and therefore effective as catalyst converters, the principal effect of the two valve **210** and **224** will be to detect and compensate for an air-fuel ratio that departs from the desired value.

Thus, the modulating valve mechanism **98** is capable of adjusting the air-fuel ratio throughout the entire temperature range of operation of an internal combustion engine, from a cold start condition through warmup and during the normal operating temperature range when the engine is hot.

The valve mechanism **98** includes further passage means to stabilize and enhance its operation. This includes a transfer passage **226** which extends from the left-hand temperature sensing chamber **176** through the central plate **112** to the passage **174** and hence into the other temperature sensing chamber **178.** This transfer passage **226** serves to amplify the reaction of the valve mechanism **98** to a change in the temperature differential T_a minus T. As an example of the operation of transfer passage **226** assume that the mixture is too lean, and therefore T tends to become higher and T_a tends to become lower. The left-hand valve **210** opens further, thus allowing more of the relatively cool bleed air to enter the chamber **176** from subchamber housing **200** (relatively cool as compared with the thermal sensing air which comes down into the chamber **176** from the catalyst bed). This added cool air causes a relatively cool flow of air through the transfer passage **226** which causes a further cooling of the sensing air passing down through the passage **174** and impinging against

the thermoelement **222**, thereby further opening the right-hand valve **224** and increasing the amount of vented air. The net result is an amplification of the effect in reducing the flow of bleed air to the signal air tube **106**, with a more rapid compensation in the enrichening direction.

Additional transfer passage means is provided in the modulating valve mechanism **98** which will cause an amplification of the modulating effect when the mixture tends to become too rich. Such additional transfer passage means includes a transfer orifice **228** which communicates between the right-hand subchamber housing **216** and the main lower housing chamber **230**, and also transfer passage **232** from the chamber **230** to the passage **172** and thence into the left-hand temperature sensing chamber **178**. Assuming too rich a mixture, T_a becomes higher and T becomes lower, so that both of the valves **210** and **224** tend to close and reduce the amount of vented air and thereby increase the amount of signal air provided to the signal air tube **106**. Such closing of the right-hand valve **224** results in an increased pressure head within the subchamber housing **216**, causing an increased flow of relatively cool bleed air from subchamber housing **216** into the lower housing chamber **230**, with a corresponding increased flow of relatively cool air through the transfer passage **232** which mixes with the temperature sensing air coming down through passage **172** that impinges upon the left-hand thermoelement **208**, thereby further cooling the thermoelement **208** and further closing left-hand valve **210** and thereby providing an increase in the flow of signal air out through the signal air tube **106**.

The communication afforded between the two temperature sensing chambers **176** and **178** by the transfer passage **226**, and also by the combination of transfer orifice **228**, lower housing chamber **230**, and transfer passage **232**, tends to stabilize the temperature condition in the two sensing chambers **176** and **178** to substantially the same temperature, so that they will be more sensitive to changes in the difference signal T_a minus T.

While the instant invention has been shown and described herein in what are conceived to be the most practical and preferred embodiments, it is recognized that departures may be made therefrom within the scope of the invention, which is therefore not to be limited to the details disclosed herein, but is to be accorded the full scope of the appended claims.

I claim:

1. In an internal combustion engine carburetor having means for sensing air flow rate therethrough, a source of fluid fuel, a first restriction for metering fuel communicating with said fuel source, a second restriction, and a fuel flow passage between said restrictions, and means connected to said sensing means for proportioning fuel flow to said air flow; the combination with said carburetor of an air-fuel mixing chamber in said fuel flow passage, a variable source of bleed air, and bleed air passage means from said bleed air source to said mixing chamber for conducting a stream of bleed air into said mixing chamber wherein the bleed air becomes mixed with the fuel so that a mixture of fuel and bleed air passes through said second restriction, thereby superimposing the effect of the bleed air on the said proportioning means by altering the pressure differential across said first restriction, whereby the rate of fuel flow is modulated by variations in the bleed air flow.

2. Apparatus as defined in claim **1**, wherein said bleed air source has a pressure generally inversely related to the rate of air flow through the carburetor so that the flow of bleed air into said mixing chamber tends to decrease with increased fuel flow and tends to increase with decreased fuel flow.

3. Apparatus as defined in claim **2**, wherein said bleed air source comprises means defining an opening in the carburetor air intake throat which faces generally downstream with respect to the flow of intake air through said throat.

4. Apparatus as defined in claim **3**, wherein said opening-defining means comprises tube means extending into the carburetor intake throat and terminating at an open end which faces generally downstream.

5. Apparatus as defined in claim **1**, wherein said mixing chamber is defined within a sleeve disposed in said carburetor between said metering and atomizing orifices, said bleed air passage means including structure defining a clearance about said sleeve and perforation means through the wall of said sleeve.

6. Apparatus as defined in claim **1**, which includes bleed air flow modulating means associated with said bleed air passage means.

7. Apparatus as defined in claim **6**, wherein said modulating means is responsive to ambient temperature changes to tend to increase the flow of bleed air to said mixing chamber in response to a temperature increase and decrease the flow of bleed air to said mixing chamber in response to a temperature decrease.

8. Apparatus as defined in claim **7**, wherein said modulating means includes vent tube means communicating with said bleed air passage means so as to vent a portion of the bleed air from said bleed air passage means and thereby decrease the flow of bleed air to said mixing chamber.

9. In an internal combustion engine carburetor having a source of fluid fuel, a fuel metering orifice communicating with said fuel source, a fuel atomizing orifice, and a fuel flow passage between said orifices, the combination with said carburetor of an air-fuel mixing chamber in said fuel flow passage, a source of bleed air, bleed air passage means from said bleed air source to said mixing chamber for conducting a straem of bleed air into said mixing chamber wherein the bleed air becomes mixed with the fuel so that a mixture of fuel and bleed air passes through the atomizing orifice, and bleed air flow modulating means associated with said bleed air passage means, said modulating means being responsive to ambient temperature changes to tend to increase the flow of bleed air to said mixing chamber in response to a temperature increase and decrease the flow of bleed air to said mixing chamber in response to a temperature decrease, said modulating means including vent tube means communicating with said bleed air passage means so as to vent a portion of the bleed air from said bleed air passage means and thereby decrease the flow of bleed air to said mixing chamber, said vent tube means having a capillary tube section therein which tends to allow less vent air to pass therethrough with an increase in ambient temperature and more vent air to pass therethrough with a decrease in ambient temperature, said bleed air passage means including stove means upstream of the communication with said vent tube means and associated with the en-

gine exhaust system, whereby the ambient temperature response of said modulating means is at least in part controlled by engine operating temperature as reflected by exhaust system temperature.

10. In an internal combustion engine carburetor having a source of fluid fuel, a fuel metering orifice communicating with said fuel source, a fuel atomizing orifice, and a fuel flow passage between said orifices, the combination with said carburetor of an air-fuel mixing chamber in said fuel flow passage, a source of bleed air, and bleed air passage means from said bleed air source to said mixing chamber for conducting a stream of bleed air into said mixing chamber wherein the bleed air becomes mixed with the fuel so that a mixture of fuel and bleed air passes through the atomizing orifice, and bleed air flow modulating means associated with said bleed air passage means, said modulating means being responsive to ambient temperature changes to tend to increase the flow of bleed air to said mixing chamber in response to a temperature increase and decrease the flow of bleed air to said mixing chamber in response to a temperature decrease, said modulating means including vent tube means communicating with said bleed air passage means so as to vent a portion of the bleed air from said bleed air passage means and thereby decrease the flow of bleed air to said mixing chamber, said bleed air passage means having a restricted orifice therein, upstream of the communication with said vent tube means so as to limit the total amount of bleed air flow.

11. In an internal combustion engine carburetor having a source of fluid fuel, a fuel metering orifice communicating with said fuel source, a fuel atomizing orifice, and a fuel flow passage between said orifices, the combination with said carburetor of an air-fuel mixing chamber in said fuel flow passage, a source of bleed air, and bleed air passage means from said bleed air source to said mixing chamber for conducting a stream of bleed air into said mixing chamber wherein the bleed air becomes mixed with the fuel so that a mixture of fuel and bleed air passes through the atomizing orifice, and bleed air flow modulating means associated with said bleed air passage means, said modulating means comprising temperature responsive valve means.

12. Apparatus as defined in claim **11,** wherein said temperature responsive valve means is responsive, at least during cold start and warm-up engine operating conditions, to ambient temperature changes to increase the flow of bleed air to said mixing chamber in response to a temperature increase.

13. In an internal combustion engine carburetor having a source of fluid fuel, a fuel metering orifice communicating with said fuel source, a fuel atomizing orifice, and a fuel flow passage between said orifices, the combination with said carburetor of an air-fuel mixing chamber in said fuel flow passage, a source of bleed air, and bleed air passage means from said bleed air source to said mixing chamber for conducting a stream of bleed air into said mixing chamber wherein the bleed air becomes mixed with the fuel so that a mixture of fuel and bleed air passes through the atomizing orifice, and bleed air flow modulating means associated with said bleed air passage means, said modulating means being responsive to air-fuel ratio changes in the carburetor output to tend to increase the flow of bleed air to said mixing chamber in response to a decrease in said air-fuel ratio and decrease the flow of bleed air to said mixing chamber in response to an increase in said air-fuel ratio.

14. Apparatus as defined in claim **13,** wherein said modulating means comprises thermally responsive valve means controlling the flow of bleed air to said mixing chamber, oxidation reaction means thermally related to said valve means to actuate the latter, and exhaust passage means connecting the engine exhaust system to said reaction means providing a flow sample of exhaust to said reaction means for oxidation of combustible ingredients therein to produce a thermal response corresponding to the richness of the carburetor mixture for actuating said valve means.

15. Apparatus as defined in claim **14,** wherein said oxidation reaction means comprises first and second oxidation reaction units each of which receives a portion of said exhaust flow sample, and means for adding air to said portion received by said second unit, the oxidation reactions in said first and second units producing respective temperatures T and T_a, said thermal response for actuating said valve means generally corresponding to the temperature differential $T_a - T$.

16. Apparatus as defined in claim **15,** wherein said oxidation reaction units comprise catalyst converters.

17. Apparatus as defined in claim **15,** wherein said valve means is arranged to control the flow of bleed air to the mixing chamber by adjustably venting a portion of the bleed air from said bleed air passage means.

18. Apparatus as defined in claim **17,** wherein said valve means is arranged to vent less bleed air causing more bleed air to flow to the mixing chamber in response to an increase in $T_a - T$ which indicates a richening of the mixture, and to vent more bleed air causing less bleed air to flow to the mixing chamber in response to a decrease in $T_a - T$ which indicates a leaning of the mixture.

19. Apparatus as defined in claim **17,** wherein said valve means comprises first and second valves thermally associated with the respective first and second oxidation reaction units, each of said valves being arranged to adjustably vent a portion of the bleed air from said bleed air passage means, said first valve tending to open with an increase in T and close with a decrease in T, and said second valve tending to open with a decrease in T_a and close with an increase in T_a, whereby the effect of said valves on the flow of bleed air to the mixing chamber is cumulative, an increase in T_a and decrease in T corresponding to a richening of the mixture causing both valves to tend to close and thereby vent less bleed air and cause more bleed air to pass to the mixing chamber to tend to lean the mixture, and conversely a decrease in T_a and increase in T corresponding to a leaning of the mixture causing both valves to tend to open and thereby vent more bleed air and cause less bleed air to pass to the mixing chamber to tend to richen the mixture.

20. Apparatus as defined in claim **19,** wherein said first valve is arranged to be substantially completely closed in a low ambient temperature range corresponding to cold start and warm-up engine operating conditions, whereby said second valve will control the flow of bleed air to the mixing chamber in such temperature range, gradual closing of said second valve as ambient temperature increases through such range resulting in a corresponding gradual increase in the flow of bleed air to the mixing chamber to gradually lean the mixture.

21. The method of improving fuel atomization in the carburetion of an internal combustion engine, which comprises the steps of passing fluid fuel through a variable fuel metering orifice, varying said fuel metering orifice in response to carburetor air flow so as to proportion fuel flow to air flow, mixing a small stream of bleed air with the metered fuel, passing the mixture of fuel and bleed air through a fuel atomizing orifice, and varying the flow of said bleed air, the effect of said bleed air being superimposed on the fuel metering orifice variations by altering the pressure differential across said fuel metering orifice, whereby the rate of fuel flow is modulated by variations in the bleed air flow.

22. The method of claim 21, wherein the rate of flow of said stream of bleed air is adjusted generally inversely according to the rate of air flow, being decreased with an increase in air flow and increased with a decrease in air flow, whereby to provide a substantial improvement in fuel atomization at low speed operating modes, while accommodating greater fuel flow during high speed operating modes when atomization is normally good.

23. The method of claim 22, wherein said adjustment of the rate of bleed air flow is accomplished by providing said bleed air from a source thereof which has a pressure generally inversely related to the rate of air flow through the carburetor.

24. The method of claim 23, wherein said source is a downstream facing pick-up opening in the carburetor air intake stream.

25. The method of claim 21, wherein said varying of the flow of bleed air is at least in part responsive to ambient temperature variations to increase the rate of bleed air flow with a temperature increase and decrease the rate of flow with a temperature decrease, to compensate at least in part for the natural tendency of a carburetor mixture to richen with a rise in ambient temperature.

26. The method of adjusting the mixture in the carburetion of an internal combustion engine, which comprises the steps of passing fluid fuel through a fuel metering orifice, mixing a small stream of bleed air with the metered fuel, passing the mixture of fuel and bleed air through a fuel atomizing orifice, and modulating the rate of flow of said stream of bleed air, said modulation comprising an increase in the rate of bleed air flow to lean the mixture and a decrease in the rate of bleed air flow to richen the mixture, said modulation being at least in part responsive to ambient temperature variations to increase the rate of bleed air flow with a temperature increase and decrease the rate of flow with a temperature decrease, to compensate at least in part for the natural tendency of a carburetor mixture to richen with a rise in ambient temperature, said modulation being rendered responsive to ambient temperature variations at least in part by venting bleed air from said stream thereof through capillary tube means which has the characteristic of passing less air therethrough with an increase in temperature.

27. The method of claim 26, which includes heating the stream of bleed air upstream of said venting in response to engine exhaust system temperature, so that said modulation is at least in part responsive to engine operating temperature variations.

28. The method of claim 27, wherein the stream of bleed air is passed through a restricted orifice upstream of said venting, so as to render the flow of bleed air upstream of said venting generally insensitive to ambient temperature changes.

29. The method of adjusting the mixture in the carburetion of an internal combustion engine, which comprises the steps of passing fluid fuel through a fuel metering orifice, mixing a small stream of bleed air with the metered fuel, passing the mixture of fuel and bleed air through a fuel atomizing orifice, modulating the rate of flow of said stream of bleed air, said modulation comprising an increase in the rate of bleed air flow to lean the mixture and a decrease in the rate of bleed air flow to richen the mixture, and sensing the air-fuel ratio of the carburetor output and performing said modulation in response to changes therein so as to increase the flow of bleed air in response to a decrease in said air-fuel ratio and decrease the flow of bleed air in response to an increase in said air-fuel ratio.

30. The method of claim 29, wherein the flow of bleed air is modulated by adjustably venting a portion of the bleed air from said stream thereof.

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