

Nov. 5, 1974

R. BAVERSTOCK
AIR-GAS MIXING DEVICE

3,846,094

Filed July 25, 1972

2 Sheets-Sheet 1

FIG. 1

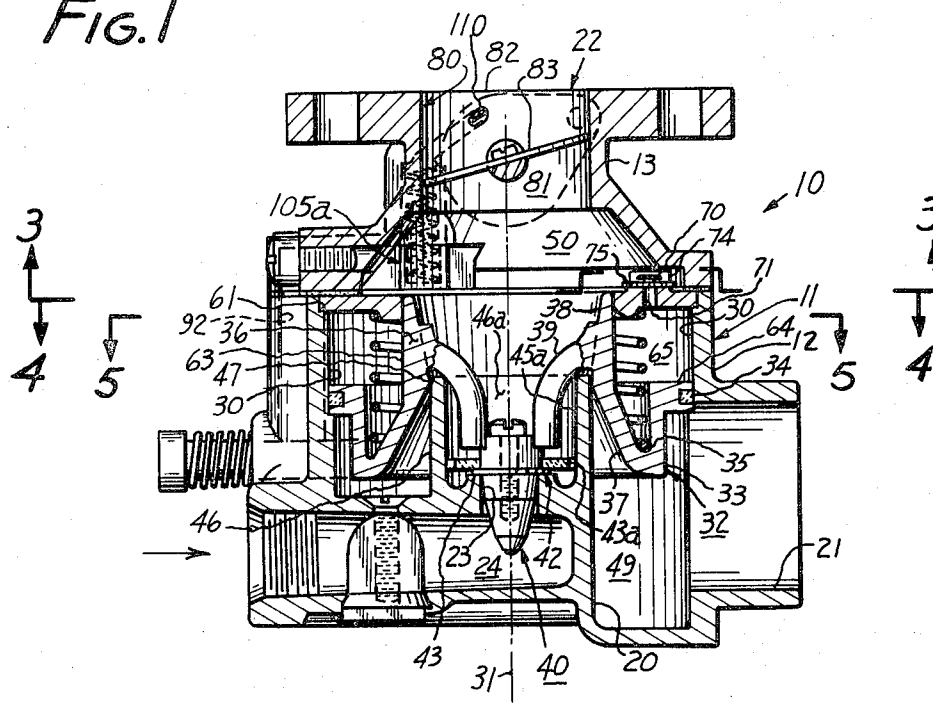
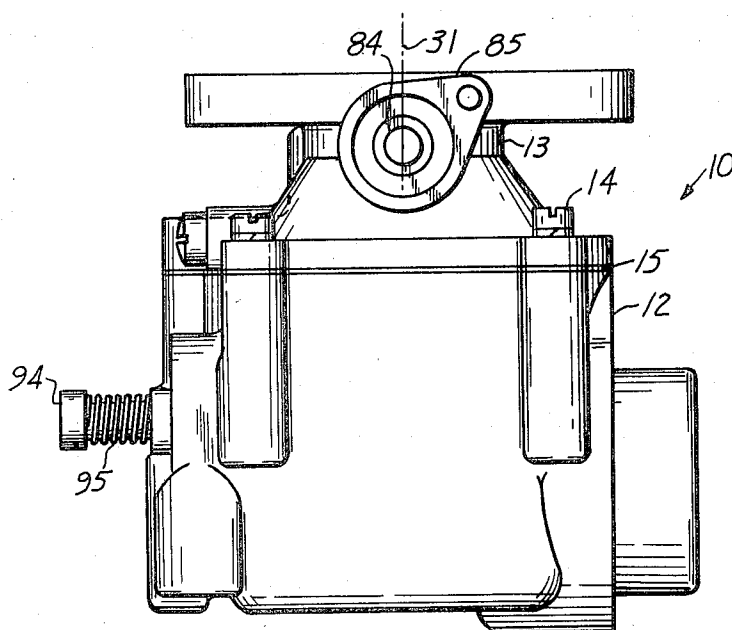


FIG. 2



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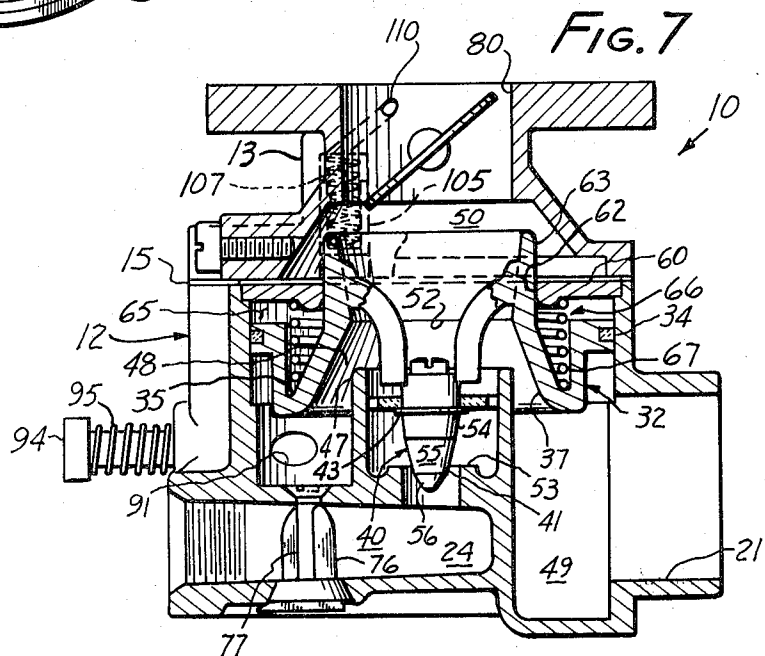
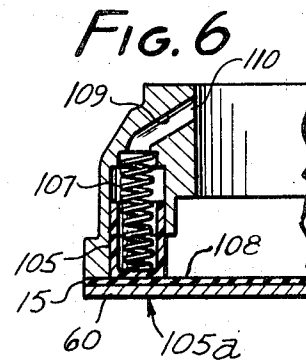
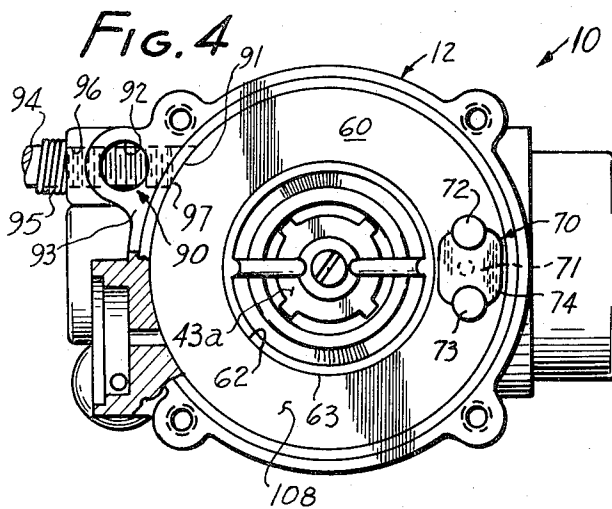
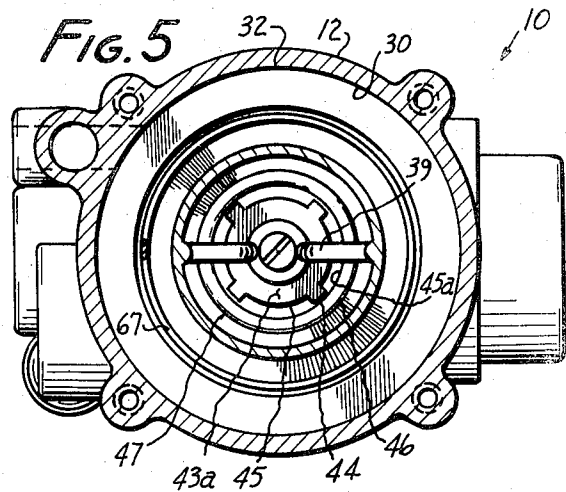
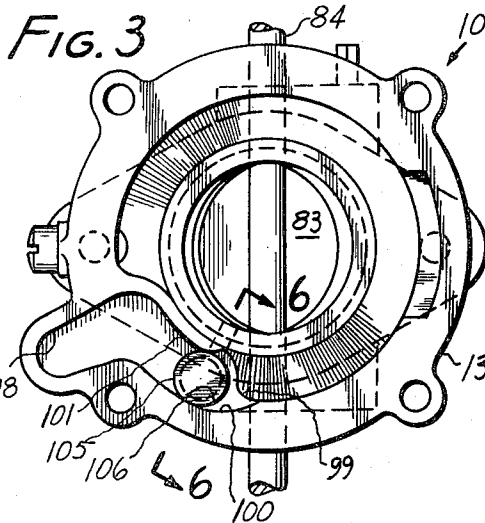
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2 Sheets-Sheet 2



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AIR-GAS MIXING DEVICE

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Filed July 25, 1972, Ser. No. 274,846

Int. Cl. F02m 21/00

U.S. Cl. 48-180 C

17 Claims

ABSTRACT OF THE DISCLOSURE

An air-gas mixing device in the nature of a carburetor used in mixing natural gas, or gasified liquefied petroleum gas, with air for fueling an internal combustion engine. The device includes a body having an interior cavity that includes a cylindrical wall in which a piston slides to open and close a gas inlet valve, and simultaneously meters the flow of air through a variable air orifice formed between two metering surfaces whose spacing apart is established by the position of the piston. An actuator chamber is formed by a member which extends across the cavity to shield the piston from backfire gases. Optionally, an air bypass passage interconnects the upstream and downstream portions of the device, so as to bypass the gas inlet valve and air metering valve, thereby to vary the leanness or richness of the mixture under certain load conditions.

This invention relates to an air-gas mixing device of the class useful as a carburetor for mixing gaseous products, such as natural gas or gasified liquid petroleum gas.

Mixing devices of the foregoing type are, of course, widely known. There exists, however, an unfilled requirement for such a device which can be shaped into a minimum bulk envelope and which, if desired, can accommodate right angle bends in the main air stream, which can produce an ultimate and properly-proportioned mixture of air and gas as a function of the position of an actuating piston whose position is responsive to demand exerted by the engine, which is protected against violent actuation by backflowing gases such as from backfires, and which includes enrichment means that come into operation under certain conditions.

It is an object of this invention to provide the foregoing advantages in a device of minimum bulk and ready produceability. It is conveniently made principally of castings which are readily assembled together, and the relationship of whose parts, one relative to another, are readily established and which require little or no effort to maintain.

An air-gas mixing device according to this invention comprises a body which has an internal cavity. An air inlet port, a mixture outlet port, and a gas inlet port enter into the cavity. A gas supply conduit is formed in communication with a gas inlet port. A cylindrical wall has a central axis and bounds a portion of the cavity. A piston makes a fluid sealing fit with the cylindrical wall, and is reciprocally moveable therein. A metering sleeve is mounted to the body, and a metering surface is formed on the metering sleeve. A metering surface is also formed on the piston, and these metering surfaces are so disposed and arranged relative to one another as to form a variable air orifice between them which has its least clearance at a first piston position. The clearance increases as the piston moves axially away from the first position. The cavity is divided at the air orifice into an upstream air chamber and a downstream mixture chamber. The gas inlet port opens into the metering sleeve. A gas valve inlet seat surrounds the gas inlet port inside the metering sleeve and lies in a plane normal to the axis of the cylindrical wall. A gas valve inlet seal is carried by the

piston which is so disposed and arranged as to close the gas valve inlet seat when the piston is in its first position and to open the gas valve inlet seat when it is moved away from its said first position. The gas conduit discharges through the gas valve inlet seat into the said metering sleeve and thence into the mixture chamber. The air inlet port opens into the air chamber, and the mixture outlet opens into the mixture chamber. A butterfly (throttle) valve may be provided downstream of the mixture chamber. Bias means forces the piston towards its said first position.

According to a preferred but optional feature of the invention, an actuator chamber wall member extends across the cavity and faces that face of the piston which is closer to the mixture chamber. The actuator chamber wall member has an opening therethrough to receive a sliding closure surface carried by the piston that makes a sliding fit in this opening. The said closure surface, actuator chamber wall member, part of the cylindrical wall, and the piston define in said cavity an actuator chamber which lies between the air chamber and the mixture chamber, the piston facing the actuator chamber on one of its faces and the air chamber on the other of its faces. An actuator passage interconnects the actuator chamber with the mixture chamber. The actuator chamber wall member shields the face of the piston which faces toward the mixture chamber from the direct blast of backfiring gases which may enter the mixture outlet port.

According to another preferred but optional feature of the invention, an air bypass passage interconnects the air chamber to the mixture chamber, and an air bypass shutoff valve is placed in the air bypass passage which is responsive to the pressure downstream of the said throttle valve, and which is biased toward its closed position. This air bypass shutoff valve opens when a relatively lower pressure is exerted on it, whereby bypass air flows through the bypass passage during normal engine operation, but does not flow when the engine is under heavy load or is starting, whereby to enrich the air-gas mixture under these two conditions.

The above and other features of this invention will be fully understood from the following detailed description and the accompanying drawings in which:

FIG. 1 is a side elevation, principally in cutaway axial cross-section, of the presently preferred embodiment of the invention;

FIG. 2 is a side elevation taken from the same point as FIG. 1, but not cut away;

FIGS. 3, 4, and 5 are cross-sections taken at lines 3-3, 4-4, and 5-5 respectively, of FIG. 1;

FIG. 6 is a fragmentary cross-section taken at lines 6-6 of FIG. 3; and

FIG. 7 is a view similar to that of FIG. 1 showing the device in another of its operating conditions.

In FIGS. 1 and 2, an air-gas mixing device 10 according to the invention is shown. It is formed with a body 11 made in two parts, a base 12 and a cap 13. The base and the cap are drawn together by fasteners 14 and a seal is made between them by gasket 15. The body includes an internal cavity 20 which is bounded by the walls of the body. It has an air inlet port 21, a mixture outlet port 22, and a gas inlet port 23. All open into the cavity. A gas supply conduit 24 is in fluid communication with the gas inlet port.

A cylindrical wall 30 is formed as a portion of the inside boundary of the cavity. It has a central axis 31 which extends vertically in FIG. 1. A piston 32 has a skirt 33 with a peripheral circular edge 34 which makes a sliding fluid sealing fit with cylindrical wall 30. A spring base 35 is formed at the bottom of skirt 33, and a re-

entrant portion 36 is formed which rises upwardly in FIG. 1 at the center of the piston.

A metering surface 37 is formed on the inside of the re-entrant portion and tapers inwardly as it extends upwardly. It is a surface of revolution and its generator line is generally straight toward its upper portion and curvilinear toward its bottom portion.

An extension 38 extends above the metering surface and attached to it is a spider 39 which extends downwardly inside the metering surface to support a metering gas pin 40 which has a tapered metering nose 41. (FIG. 7).

A gas valve inlet seal 42 is attached to the piston next to the metering pin.

It may conveniently be washer-shaped, with a sealing plane 43 which lies normal to the central axis 31. This central axis is also the axis of the piston when it is fitted in the cylindrical wall. A gas deflector plate 43a (sometimes called a deflector) is also attached to the piston just above the gas inlet seal. It has an imperforate central portion and a plurality of arms 44 (FIG. 5) between which there are formed notches 45 through which gas which is admitted by the gas inlet valve will pass. This deflector plate thereby acts to deflect the entering gas away from the central axis and toward and against cylindrical wall 45a of a metering sleeve 46. The metering sleeve 46 is integral with the body and surrounds the gas inlet port. It has an axial passage 46a from the gas inlet port to the mixture chamber. The gas deflector plate moves up and down inside the axial passage formed by wall 45a, and wall 45a confines the gas to this passage until it reaches the upper end of the metering sleeve. A metering surface 47 is formed at the free end of metering sleeve 46. Metering surfaces 37 and 47 cooperate with each other to form a variable air orifice 48 (see FIG. 7), which orifice divides the cavity into an upstream air chamber 49 and a downstream mixture chamber 50.

The piston is shown in its "first position" in FIG. 1, wherein the clearance between metering surfaces 37 and 47 is at a minimum. There may be some clearance at this variable air orifice at all times. Alternatively, there may be a full closure, depending upon the objectives of the installation. It will be noted that some portions of the outside of the metering sleeve and of the inside of the piston extension 38 overlap each other, and that for an initial portion of the upward movement, the clearance at the orifice may not change appreciably. The clearance will, however, change significantly when the piston has moved upwardly beyond where edge 52 (FIG. 7) on the piston passes upwardly beyond metering surface 47.

A gas valve inlet seat 53 surrounds the gas inlet port. This seat is planar and circular, and lies in a plane normal to the axis 31 of the cylindrical wall 45a. Seat 53 is so disposed and arranged as to be contacted and closed by the gas valve inlet seal carried by the piston when the piston is in its first position. It will be noted that metering pin 40 is generally circular in section taken normal to its axis of movement, and has an initial cylindrical portion 54 which has a slight, if any, taper, whereby the initial upward movement of the piston will cause little, if any, opening of the gas valve past the gas inlet port, just as little opening for air flow will be made past the metering surfaces during the initial upward portion of the piston's movement. Below that, tapered portions 55 and 56 on the metering pin establish different rates of gas flow, depending on the vertical location of the piston relative to the gas valve inlet seat. A source of gas supply, not shown, is to be connected to gas supply conduit 24, and air inlet port 21 is open to the atmosphere or connected to it through an air filter. Mixture outlet port 22 is connected to the manifold of the engine or to the cylinder intake ports, as appropriate.

An actuator chamber wall member 60 (FIG. 7) is peripherally attached to the body and extends into the cavity from its edges. It may conveniently be seated on a

step, and be held in place by compression between the base and cap when they are joined. The actuator chamber wall member includes a central circular opening 62 which is concentric with central axis 31. A sliding closure surface 63 is formed on the outside of the re-entrant portion of the piston. It is cylindrical, and makes a close sliding but not necessarily sealing fit with the inside wall of opening 62 in the actuator chamber wall member. A portion of the cylindrical wall 30, the upper face 64 of the piston, the closure surface 63 and the actuator chamber wall member 60 together define an actuator chamber 65.

Bias means 66 in the form of a coil spring 67, which is seated on the spring base 35 and which also bears against the actuator chamber wall member biases the piston towards the first position illustrated in FIG. 1.

A check valve 70 (see FIGS. 1 and 4) which may be a conventional flapper valve, is mounted to the actuator chamber wall member. An actuator passage 71 passes through the actuator chamber wall member, and flow therethrough is controlled or retarded by check valve 70. This may be a conventional check valve which includes a pair of headed pins 72, 73 that loosely restrain a flapper plate 74. This plate can rise and fall relative to a seat 75 which surrounds the downstream opening of passage 71. Accordingly, the check valve permits ready flow from actuator chamber 65 and retards their entry into it. Because gases will have to ultimately flow into actuator chamber 65 for the piston to move downwardly, this valve may either be somewhat leaky, to permit such flow, or it may be a sealing type valve, and a suitable clearance may be formed between the wall of opening 62 and closure surface 63 for such flow. In any event, the actuator chamber wall member will shield that portion of the upper face 64 of the piston which lies radially outside of the sliding closure surface 63 from the direct blast of backfire gases which may come down from the mixture outlet port. This substantially reduces the downward forces on the piston under these conditions, especially because a substantial proportion of the area of the piston lies outside the sliding closure surface 63.

A trim valve 76 in the form of a rotatable blade and paddle 77 is placed in the gas conduit to provide a fixed but adjustable control over the maximum rate of flow of gas into the valve.

A throat 80 forms a portion of a mixture outlet passage 81 downstream of the mixture chamber, which mixture chamber, for convenience, will be defined as terminating at edge 82. The upstream portion of this device originates at the gas and air inlet ports. The other portions of it are downstream. In the throat, there is disposed a throttle valve 83 (sometimes called a "butterfly") which is pivotally mounted to a shaft 84 in accordance with known arrangements. The mixture outlet passage 81 is itself directly connected to the manifold or some other mixture intake element of a demand unit such as an internal combustion engine.

The mixing device as shown in its repose, closed, condition in FIG. 1 with the butterfly closed and in a position such that the engine would be shut down. The piston is in its first position. A linkage 85 (FIG. 2) may be mounted to the shaft for opening and closing the butterfly in accordance with known linkage constructions.

An air bypass passage 90 bypasses the variable air orifice 48. It has a bypass inlet port 91 (FIG. 7) which opens into the interior wall of the upstream air chamber and extends as a passage 92 (FIG. 4) vertically to a face 93 which opens on top of the base 12. A restrictor 94, comprising a threaded screw with a spring 95 to hold it in an adjusted position, is threaded into a thread-tapped hole 96 so that at its forward edge 97 it provides a fixed but adjustable metering restriction on the volume of air which can pass through the air bypass passage 90. The gasket is

ported above passage 92 so that passage 92 is in direct communication with a channel 98 which runs along the bottom face of cap 13 above the gasket. In turn, this channel forms part of the bypass passage and opens through a second bypass port 99 in the wall of the mixture chamber. As can be seen in FIG. 3, the channel is bounded by a pair of opposite walls 100, 101, both of which terminate at the wall of the mixture chamber in the cap.

An air bypass shutoff valve 105a (FIGS. 3 and 6) includes a valve plunger 105 which is slidably fitted in valve chamber 106. The plunger is cup-shaped, and is spring-biased by a spring 107 seated in it and opposed to the cap into contact with a flat face 108 on the gasket or on the base, and its periphery is shaped such (see FIG. 3) that it extends between walls 100 and 101 so as to close the air bypass passage when it bears against face 108 and these two walls. It will permit passage of air past it when it is drawn upwardly. The valve 105a therefore comprises the plunger 105, walls 100 and 101, and face 108 on gasket 15.

Bypass valve power passage 109 (FIG. 6) connects valve chamber 106 on the opposite side of plunger 105 from passage 90 to a region in throat 80 downstream of the throttle valve 83. Passage 109 opens into this region at port 110. Thus, port 110 and passage 109 are exposed to engine demand pressures, i.e., the pressures in the engine manifold or intake downstream of the throttle valve (butterfly). Therefore, when the manifold pressure is relatively low, this lower pressure is exerted on the upper face of valve plunger 105 to pull it up. When the resulting force is insufficient to overcome the bias of spring 107, the plunger will seat on the gasket and close the air bypass passage 90.

The air-gas mixing device is installed by attaching its body to the engine or other support. The air inlet port may be directly open to the atmosphere, or may receive air from an air filter, when open to the atmosphere.

The gas supply conduit 24 is connected to a source (not shown) of natural gas or gasified liquefied petroleum gas, or such other gaseous fluid as is being mixed with air. The throat is connected to the engine intake manifold or to such other point of demand as the demanding mechanism (engine) may provide. The trim valve is set so as to exert a fixed limitation on the maximum rate of flow of gas, and the restrictor 94 will be adjusted when the engine is running for the correct rate of bypass air flow through air bypass passage 90.

With the engine shut down, as in the position of FIG. 1, the force of coil spring 67 will force the piston assembly in a downward direction in FIG. 1 so that the gas valve inlet seal bears against the gas valve inlet seat and the gas inlet port 23 is therefore closed. The strength of the spring is selected to accomplish this purpose, and this provides a reliable gas shutoff when the engine is shut down. Under these circumstances, the piston is exposed to atmospheric pressure on both sides, and the only differential pressure tending to open it is that which is exerted across the gas inlet port, which, as stated above, is resisted by bias means 66.

Now, assuming that the engine is to be started, it is desirable under these circumstances, and also under the circumstances of heavy load, to enrich the mixture. This is accomplished in the present invention by closure of the air bypass passage 90. Under these conditions, the pressure in the throat, and therefore in the engine intake manifold, is relatively close to atmospheric. This is sometimes of as a low vacuum, or high manifold pressure. Under these circumstances, the pressure which appears at port 110, and therefore at the top of valve plunger 105, is insufficient to raise the plunger, so that the bypass passage remains closed. Accordingly, when the engine is started and the butterfly valve is open, a negative pressure is ex-

erted in the downstream mixture chamber which is low enough to exert a negative force tending to lift the piston, but which is insufficient to lift the valve plunger. Accordingly, the flapper valve 74 of the check valve 70 will be lifted, the negative pressure will enter the actuator chamber 65, and the bias force of spring 67 will be overcome, the piston will begin to rise, and the gas inlet valve seal will be lifted from the gas valve inlet seat and after a sufficient axial movement of the piston, cylindrical portion 54 of the metering pin will be removed from the gas inlet port also the tapered portion of the metering surface 37 will have passed metering surface 47 so that air can flow through the air valve. The gas will have been deflected by the deflector plate 43a and will tend to flow up the side of the inner wall of the metering sleeve at the end of which it meets the inwardly-directed air stream so as to mix thoroughly just downstream of the variable air orifice. It may be commented here that it is not necessary for the air valve to make a complete closure, but that it will be necessary at all times for it to exert some kind of metering effect. The gas valve, of course, must reliably be closeable.

It will now be noted that the farther the piston moves vertically in FIGS. 1 and 7, the wider open will be the gas valve and the air orifice, so as to provide an accurately adjusted mixture, the proportions can reliably be selected by proper selection of the dimension of the metering pin and the metering surfaces.

When the engine is shut down, it is desirable for the piston not to slam to its first (closed) position, and this is also especially the case in the event of backfires. Previous devices, especially those which have utilized diaphragms for actuation have often been destroyed by backfires, because the sudden reverse forces have been more than their constructions could withstand. In the event of the quick reduction of pressure or a quick reversal of pressure, the downward movement of the piston is slowed because the volume in actuator chamber 65 would have to increase to permit the piston to move, and the check valve will, of course, close, or if it is in the nature of a restrictor-type valve, will bleed only very slowly. Alternatively, there may be clearance between the metering sleeve and the opening in the actuator chamber wall member 60 to provide the necessary restricted bleed. In any event, a sudden reversal of pressure or a quick drop in demand will not cause a slamming closure of the piston.

In a normal operation in which there is a relatively high vacuum (low atmospheric pressure) in the demand manifold, there will be a relatively low pressure applied to port 110 and this will cause valve plunger 105 to rise and permit the flow of supplemental air past valve 105a to the mixture. This leans down the mixture for most effective operation at normal operating conditions, such as cruising. However, in the event of a suddenly increased demand, then the pressure would rise in the manifold, the plunger 105 would again move down as shown in FIG. 1, and the bypass passage would be closed, thereby enriching this mixture during this event.

It will be noted that this device is quite compact. The air chamber is substantially peripherally disposed around the gas valve and can be entered at right angles to its discharge direction. The gas conduit may also enter the body as a conduit which makes a right angle directly to the gas inlet valve. All of the elements may generally be concentric, i.e. the actuator chamber, the air chamber, the mixture chamber, the gas valve and the air valve so that the device is readily manufactured to close tolerances, and requires little, if any, adjustment in use. It may be made small enough to fit in close quarters such as are common in forklift installations.

This invention is not to be limited by the embodiment shown in the drawings and described in the description, which is given by way of example and not of limitation, but only in accordance with the scope of the appended claims.

I claim:

1. An air-gas mixing device comprising: a body having an internal cavity, an air inlet port, a mixture outlet port and a gas inlet port, said ports opening into said cavity; a gas supply conduit in communication with the gas inlet port; a cylindrical wall having a central axis and bounding a portion of said cavity; a piston having a pair of faces and making a fluid-sealing sliding fit with said cylindrical wall, and reciprocally movable therein; a metering sleeve; a metering surface on said metering sleeve, and a metering surface on said piston, said metering surfaces being so disposed and arranged relative to one another as to form a variable air orifice between them, the least clearance of which exists at a first piston position, the clearance increasing as the piston moves axially away from said first piston position, said cavity being divided at the said air orifice into an upstream air chamber and a downstream mixture chamber, the gas inlet port opening into the said metering sleeve; a gas valve inlet seat surrounding said gas inlet port inside said metering sleeve, and lying in a plane normal to the axis of the cylindrical wall, and a gas valve inlet seal carried by the piston so disposed and arranged as to close the gas valve when the piston is in the said first position, and to open the gas valve when the piston is moved away from the said first position, the gas supply conduit discharging through the gas valve seat into the said metering sleeve and thence into the mixture chamber, the air inlet port opening into the air chamber, and the mixture outlet port opening into the mixture chamber; bias means forcing the piston toward its said first position; an actuator chamber wall member extending across the cavity and facing one face of said pair of faces, said one face closer to the mixture chamber, the actuator chamber wall member having an opening therethrough; a sliding closure surface carried by the piston making a sliding fit in said opening, whereby the said closure surface, actuator chamber wall member, part of said cylindrical wall, and the said one face of the piston define in said cavity an actuator chamber which lies between the air chamber and the mixture chamber, the piston facing the actuator chamber at said one face, and the air chamber at the other face of said piston, the device having an actuator passage interconnecting the actuator chamber with the mixture chamber, the actuator chamber wall member shielding the said one face of the piston which faces toward the actuator chamber wall member from the direct blast of backfiring gases which may enter the mixture outlet port.
2. An air-gas mixing device according to claim 1 in which a check valve is placed in said actuator passage to permit ready outflow of gases from the actuator chamber and to retard flow of gases into the actuator chamber.
3. An air-gas mixing device according to claim 1 in which the bias means comprises a resilient spring.
4. An air-gas mixing device according to claim 3 in which a check valve is placed in said actuator passage to permit ready outflow of gases from the actuator chamber and to retard flow of gases into the actuator chamber.
5. An air-gas mixing device according to claim 1 in which a gas metering pin is attached to said piston, said gas metering pin projecting through said inlet seat in some of its axial positions, and having a varying cross-sectional area so as to form a restricted opening at the inlet seat which varies in cross-section as a function of the piston's axial distance from its said first position.
6. An air-gas mixing device according to claim 5 in which the gas valve inlet seal and the gas metering pin are supported by a spider which extends into the said metering sleeve.
7. An air-gas mixing device according to claim 1 in which a throttle valve is placed downstream of the mixture chamber, an air bypass passage interconnects the air chamber to the mixture chamber, and in which an air bypass shutoff valve is placed in the air bypass passage

which is responsive to engine demand pressures downstream of the throttle valve, and which is biased so as to assume a closed condition under relatively higher pressure, and which opens under relatively lower demand pressures, whereby bypass air flows through the bypass passage during normal engine operation, but does not flow therethrough when the engine is under heavy load or when starting, whereby to enrich the air-gas mixture under heavy load or starting conditions.

8. An air-gas mixing device according to claim 1 in which the cylindrical wall, the metering surfaces, the gas valve inlet seat, the gas valve inlet seal, and the closure surface are circular and concentric.

9. An air-gas mixing device according to claim 1 in which the metering sleeve has an axial passage leading from the mixture chamber to the gas inlet port, and in which a gas deflector is carried by the piston to deflect gas entering the metering sleeve from the gas inlet port toward the wall of said axial passage.

10. An air-gas mixing device according to claim 1 in which the metering surface on said piston narrows as it extends toward the mixture chamber, whereby air is deflected by it inwardly toward the said axis to converge upon the gas stream emanating from the metering sleeve.

11. An air-gas mixture device according to claim 10 in which the metering sleeve has an axial passage leading from the mixture chamber to the gas inlet port, and in which a gas deflector is carried by the piston to deflect gas entering the metering sleeve from the gas inlet port toward the wall of said axial passage.

12. An air-gas mixture device according to claim 11 in which the cylindrical wall, the metering surfaces, the gas valve inlet seat, the gas valve inlet seal, and the closure surface are circular and concentric.

13. An air-gas mixing device comprising: a body having an internal cavity, and air inlet port, a mixture outlet port, and a gas inlet port, said ports opening into said cavity; a gas supply conduit in communication with the gas inlet port; a cylindrical wall having a central axis and bounding a portion of said cavity; a piston having a pair of faces and making a fluid-sealing sliding fit with said cylindrical wall, and reciprocally movable therein; a metering sleeve; a metering surface on said metering sleeve, and a metering surface on said piston, said metering surfaces being so disposed and arranged relative to one another as to form a variable air orifice between them, the least clearance of which exists at a first piston position, the clearance increasing as the piston moves axially away from said first piston position, said cavity being divided at the said air orifice into an upstream air chamber and a downstream mixture chamber, the gas inlet port opening into the said metering sleeve; a gas valve comprising a gas valve inlet seat surrounding said gas inlet port inside said metering sleeve and lying in a plane normal to the axis of the cylindrical wall, and a gas valve inlet seal carried by the piston so disposed and arranged as to close the gas valve when the piston is in the said first position, and to open the gas valve when the piston is moved away from the said first position, and the gas supply conduit discharging through the valve seat into the said metering sleeve and thence into the mixture chamber, the air inlet port opening into the air chamber, and the mixture outlet port opening into the mixture chamber; bias means forcing the piston toward its said first position; a throttle valve downstream of the mixture chamber, the device having an air bypass passage interconnecting the air chamber to the mixture chamber; an air bypass shutoff valve in the air bypass passage which is responsive to engine demand pressures downstream of the throttle valve, and which is biased so as to assume a closed condition under relatively higher demand pressures, and which opens under relatively lower demand pressures whereby bypass air flows through the bypass passage during normal engine operation, but does not flow therethrough when the engine is under heavy

load or when starting, whereby to enrich the air-gas mixture under heavy load and starting conditions.

14. An air-gas mixing device according to claim 13 in which the air bypass shutoff valve comprises a plunger exposed at one end to engine demand pressures, and a spring biasing the plunger to a position such as to close the air bypass shutoff valve.

15. An air-gas mixing device according to claim 7 in which a check valve is placed in said actuator passage to permit ready outflow of gases from the actuator chamber and to retard flow of gases into the actuator chamber.

16. An air-gas mixing device according to claim 9 in which a check valve is placed in said actuator passage to permit ready outflow of gases from the actuator chamber and to retard flow of gases into the actuator chamber.

17. An air-gas mixing device according to claim 11 in which a check valve is placed in said actuator passage

to permit ready outflow of gases from the actuator chamber and to retard flow of gases into the actuator chamber.

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48—180 A, 184; 123—120; 261—50 A, 63