April 22, 1958 G. N. MILES 2,831,757

APPARATUS FOR SUPPLYING GASEOUS FUEL TO AN INTERNAL COMBUSTION ENGINE

Filed March 11, 1954 2 Sheets-Sheet 1

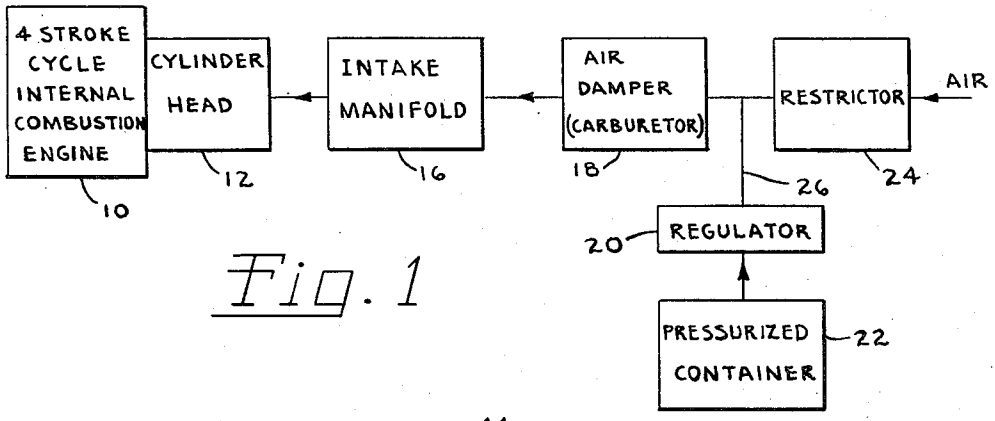


Fig. 1

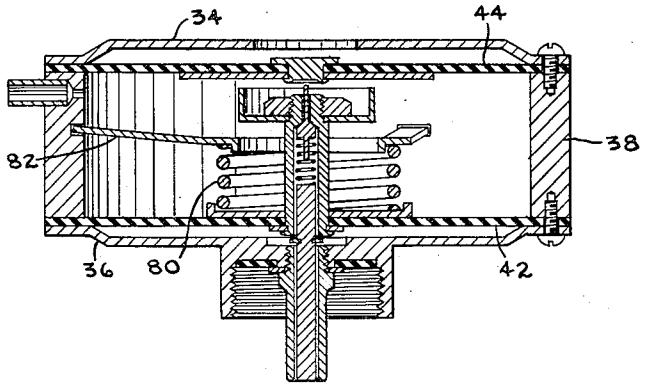


Fig. 4.

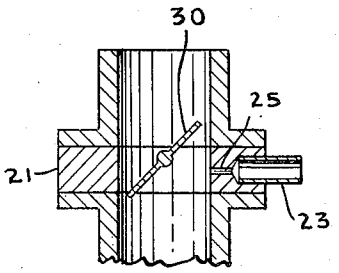


Fig. 3.

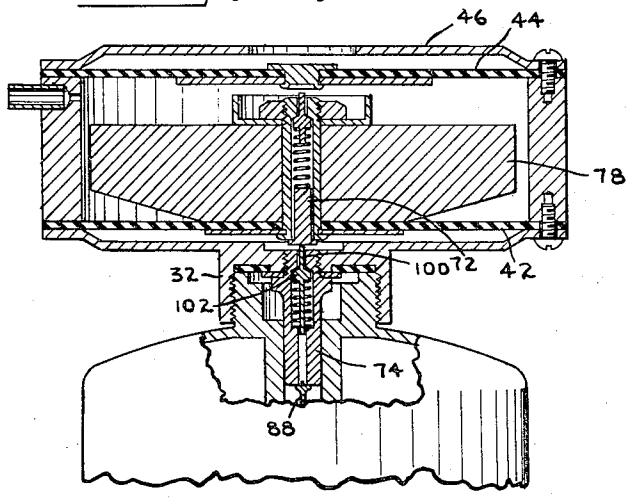


Fig 5

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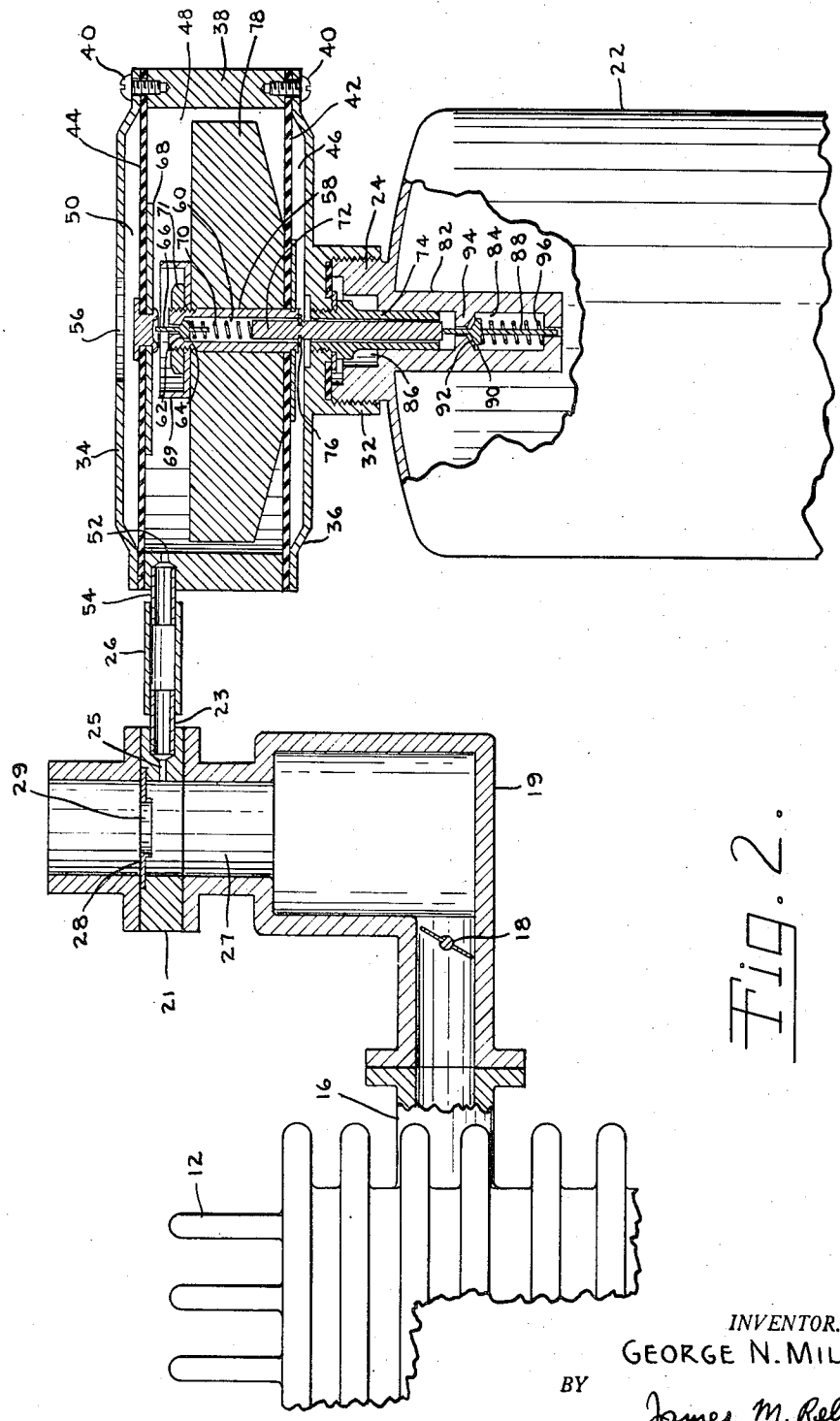


Fig. 2.

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APPARATUS FOR SUPPLYING GASEOUS FUEL TO AN INTERNAL COMBUSTION ENGINE

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Application March 11, 1954, Serial No. 415,597

7 Claims. (Cl. 48—184)

This invention relates to improvements in fuel supply apparatus for internal combustion engines, and particularly to an improved arrangement for supplying gaseous fuel to an internal combustion engine of the four-stroke-cycle type.

The gasoline burning, four-stroke-cycle internal combustion engine is continually being adapted to new uses, particularly in such apparatus as power lawnmowers and the like used about the home. While these engines generally are satisfactory, one of the principal objections to their use has been the necessity for handling gasoline as a fuel. Gasoline cannot be sent by mail or parcel post to isolated localities such as farms, country estates and the like. Therefore, the user must make arrangements to pick up gasoline at intervals if it is used as a fuel. Furthermore, the storage of gasoline is a definite problem, as there are rather rigorous storage restrictions in some localities. Again, many users object to handling gasoline due to the likelihood of spillage in transfer from the container to the engine fuel tank.

There is, however, a readily available fuel which has none of the foregoing disadvantages, and which is well suited for use with internal combustion engines, particularly those of, say, one to three horsepower. Such fuel is a hydrocarbon gas, such as propane or butane. With improved techniques for bottling these gases in liquid form in small, easily handled containers, the attractiveness of gaseous fuel for use with internal combustion engines increases greatly. This is particularly true in the case of currently available throw-away type containers of such gas that occupy very little storage space, that are clean and easy to handle, and that are approved for parcel post shipment by the Government agencies concerned. Aside from convenience of handling, this fuel has the additional advantage that it vaporizes readily and thereby facilitates engine starting.

On the other hand, the more commonly available engines of the type under consideration have been designed for burning gasoline, and require modification to operate on such gaseous fuel.

Among the problems to be considered in the operation of an internal combustion engine on gaseous fuel is that of properly regulating and controlling the supply of fuel to the engine. For one thing, provision must be made to keep the gas supply rate reasonably independent of changes in gas pressure which accompany changes in the temperature of the fuel container. A second problem is that of maintaining the correct mixture-ratio between the air and the fuel gas supplied to the engine so that the engine will idle properly without excessive fuel consumption, will accelerate quickly, and will operate smoothly at high speeds. An additional problem arises when the engine is shut off. In a liquid fuel supply system, the flow of fuel can be cut off automatically by a simple carburetor float valve or the like. Accordingly, if the operator forgets to close the manual fuel valve when the engine stalls or when it is stopped by shorting the ignition, the

float valve will prevent waste of fuel. In using a gaseous fuel supplied from a pressurized container, some arrangement comparable to the gasoline carburetor float valve is highly desirable to avoid fuel waste, as there is the same likelihood that the operator will forget to close a manual valve.

It is among the objects of the present invention to provide an improved apparatus for supplying gaseous fuel to a four-stroke-cycle internal combustion engine. Another object of the invention is to provide a simple and inexpensive assembly for readily adapting gasoline burning engines to utilize gaseous fuel. A further object is to provide a gaseous fuel supply apparatus particularly adapted for use with throw-away containers of liquified hydrocarbon gas. Another object of the invention is the provision of an improved gaseous fuel supply system wherein the flow of fuel will start automatically when the engine is cranked and will stop automatically when the engine is stopped, without manipulating any manual valve.

In accordance with a preferred embodiment of the invention, the foregoing and other related objects are attained in a gaseous fuel supply apparatus which includes a simple gas regulation device adapted (1) to regulate the gas supply pressure, (2) to control the flow of gaseous fuel as a function of the control of the air supplied to an internal combustion engine, and (3) to turn on and off the supply of fuel when the engine is started or stopped. More specifically, the regulator is arranged to respond to changes in pressure in the engine air intake system to supply the proper amount of fuel at all times during operation, or none at all when the engine is not running. In accordance with one feature of the invention, a simple assembly of parts is provided for readily adapting an engine designed for normal operation on gasoline to operate equally well on gaseous fuel. It will be understood, however, that the successful and advantageous practice of the invention is not limited to conversion installations, as many of the features of the invention are of equal utility in engines designed to operate on gaseous fuel.

A more complete understanding of the invention, and of further objects and features thereof, can be had by reference to the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawing, wherein,

Figure 1 is a block diagram showing the general relationship between the parts in a system embodying the invention,

Figure 2 is a side elevation, partly in section, showing in detail the parts in a system corresponding to that shown in Figure 1,

Figure 3 is a section view of a variable restrictor that can be used in the system of Figure 2,

Figure 4 is a section view of a regulator similar to that shown in Figure 2, but with a spring replacing the weight on the lower diaphragm, and

Figure 5 is a fragmentary view, similar to Figure 2, of a modified embodiment of the invention.

The system shown in Figure 1 includes a four-stroke-cycle internal combustion engine **10** having a cylinder head **12**. It will be understood that the head **12** will include the usual intake valve (not shown) through which a mixture of air and fuel is supplied to the engine cylinder. In the usual case, this intake valve will be connected to an air-fuel supply system which includes an intake manifold **16**. Upstream of the manifold **16**, a gasoline-burning engine will include a carburetor for mixing air and fuel. The carburetor usually will include a butterfly valve or the like for controlling the flow of air to the engine. In an engine designed specifically for burning gaseous fuel, while no carburetor is required, the air in-

take again will include an air valve or damper. Accordingly, in the generalized case presently being considered, the system is shown to include an air damper **18** upstream of the manifold **16**, it being understood that the damper **18** may be part of a carburetor.

In accordance with the present invention, there is provided a regulator **20** for controlling the supply of gas to the engine **10** from a container **22**. As will be explained more fully hereinafter, the regulator **20** includes pressure-sensing means for controlling the gas flow in response to pressure in the engine intake system. A line **26** from the regulator to the upstream side of the damper **18** serves both as a pressure-sensing connection for controlling the regulator and as a conduit for supplying fuel to the engine. On the air inlet side of the regulator line **26**, a restrictor **24** is provided for introducing a pressure drop in the intake system.

It will be understood that when the engine **10** is cranked to start it, or when it is running with the air damper **18** substantially completely closed (engine idling), very little air will flow through the engine intake system and there will be only a slight pressure drop across the restrictor **24**. The regulator **20** is so designed that this slight pressure drop will be enough to move a diaphragm for opening an on-off valve in the regulator. It will also be sufficient to control a second valve which regulates the flow of gas from the container to the engine.

When the damper **18** is substantially fully opened, as when the engine is operated at high speed, the pressure drop across the restrictor will be considerably greater. In the regulator, this increased pressure drop is utilized to increase the flow area through the regulating valve to supply more fuel to the engine. When the engine is shut off, as by shorting the ignition, the diaphragm controlling the on-off valve in the regulator will return to a neutral position, permitting the on-off valve to close whereby to shut off the supply of fuel to the engine, while the regulating valve remains partly open in readiness for restarting of the engine.

In Figure 2 there is shown an apparatus for modifying a gasoline engine in accordance with the present invention to operate on gaseous fuel. The elements of the apparatus shown in Figure 2 include the engine cylinder head **12** which is connected to an air intake system including a manifold **16** and carburetor **19**, the other parts of the engine being omitted for simplicity.

The air damper in this case comprises a butterfly valve **18** in the carburetor. On the upstream side of the carburetor **19**, where a flange connection normally would be made to an air filter (not shown), a "spacer pad" **21** is inserted, providing communication, through a stub **23** and a port **25** in the pad, between the carburetor air inlet port **27** and a tube **26**. The tube **26** communicates with the fuel regulator as explained hereinafter, and is preferably made of flexible material, such as rubber, to facilitate mounting the regulator and fuel container at any convenient point on the engine frame.

The pad **21** is recessed on the upstream side of the port **25** to receive a disc **28** having a central opening **29**. The disc functions as a restrictor in the air intake system. While a disc with a fixed diameter central opening will serve satsfactorily for any one engine, for engines of different size it is sometimes necesary to vary the diameter of the opening to adapt properly to the air flow of the particular engine concerned. Accordingly, in a conversion kit applicable to engines of different horsepower ratings, it is desirable to have the restrictor in the form of a readily removable disc for convenience in interchanging discs. Alternatively, as shown in Figure 3, the restrictor can be in the form of a butterfly valve **30** constituting an adjustable-area restrictor.

The fuel supply container in the system of Figure 2 comprises a metal bottle **22** having reduced diameter, threaded neck **24** to which the regulator **20** is adapted to be assembled by means of a threaded socket **32**.

The regulator comprises a housing made up of upper and lower dish-shaped plates **34**, **36** assembled to a separating ring **38** by screws **40** or the like. A first flexible diaphragm **42** is clamped between the lower plate **36** and the separating ring **38**, while a second diaphragm **44** is clamped between the separating ring and the upper plate **34**. The two diaphragms **42**, **44** extend across and divide the space inside the regulator housing into lower, intermediate and upper compartments, **46**, **48**, and **50**, respectively. A port **52** in the separator ring **38** is connected by a stub **54** to the tube **26**, thereby communicating the pad port **25** with the intermediate compartment **48**. An opening **56** in the upper housing plate **34** opens the upper compartment **50** to atmosphere.

The lower diahragm **42** carries a valve body **58** having a central passage **60** which communicates between the lower and intermediate compartments **46**, **48**. At the upper end of the passage **60**, a tapered annular shoulder **62** provides a valve seat cooperable with a spring-loaded valving element **64** to close the passage **60**. The valve element **64** has a stem **66** which projects through the open upper end of the valve body **58** and terminates just below a pressure plate **68** at the center of the upper diaphragm **44**. A collar **69** is provided surrounding the stem **66** and held in place by a nut **71**. This collar normally will not contact the pressure plate **68**, but merely protects the diaphragm **44** against overstress due to overtravel caused by any sudden extreme pressure change.

The actuating spring **70** for the valve element **64** extends from the element **64** to the upper end of a rod **72** which fits loosely in the lower end of the valve body passage **60**. The rod **72** extends through a guide tube **74** which projects from the housing inside the socket **32**.

The rod **72** is provided with a retaining ring **76** fitting in an annular groove in the outside wall of the rod. The ring **76** limits the movement of the rod downwardly by contact with the lower housing plate **36** and upwardly by contact with the lower face of the diaphragm **42**.

As will be explained hereinafter, a balancing force is needed on the lower diaphragm **42**, acting in a direction to move the diaphragm toward the lower housing plate **36**. This force can be provided either by a weight **78** resting on the lower diaphragm **42** as shown in Figure 2, or by a spring **80** extending from the lower diaphragm **42** to a spider plate **82** fixed to the inner wall of the separating ring **38** beneath the upper diaphragm **44**, as shown in Figure 4.

The type of container with which the regulator being described customarily will be used includes a valve in the gas outlet passage which is adapted to be opened by a projecting rod on the fitting to which the bottle is assembled. In one commonly available type of container, this bottle valve comprises a spring-loaded valve suitable for use with the regulator structure of the present invention as a regulating valve.

In the apparatus shown in Figure 2, for example, the bottle valve comprises a body **82** having a longitudinal passageway **84** which communicates between the inside of the bottle and the neck opening **86**. In this passageway **84** is located a valving element comprising a stem **88** having an enlarged portion **90** intermediate its ends with a tapered upper surface **92** adapted to seat against the undersurface of a correspondingly tapered shoulder **94** forming a seat in the passageway **84**. A spring **96** urges the stem **88** upwardly to bring the valving member into contact with the seat when the valve is to be closed.

When the fuel bottle and housing are disassembled, the valve element **90** will seat against the shoulder **92** to prevent the escape of fuel from the bottle. However, when the fuel bottle is screwed into the socket **32**, the rod **72** projects into the opening **86** in the neck of the container, as shown, to contact and depress the stem **88** of the bottle valve. This will permit gas to flow from the container through the passageway **84** and through the guide tube **74** into the lower regulator compartment **46**. From

the lower compartment, the gas will flow into the passage 60 in the valve body 58. As long as the upper diaphragm 44 is in neutral position, as shown, the valve 64 immediately beneath the upper diaphragm will remain closed and no gas will flow through the regulator. In other words, once the bottle is attached to the regulator, the lower housing compartment 46 and the passage 60 will fill with fuel gas, awaiting opening of the upper valve 64 to admit gas to the intermediate compartment 48 and thence through the separator port 52 and the tube 26 to the engine intake system.

When the engine is cranked, some air will be drawn into the engine through the air intake system, creating a pressure drop across the restrictor 28. The sub-atmospheric pressure on the downstream side of the restrictor will be communicated through the connecting tube 26 to the intermediate housing compartment 48. Since the uppermost housing compartment 50 is open to atmosphere, the pressure difference across the upper diaphragm 44 will flex the diaphragm downwardly, thereby opening the on-off valve 64. This will allow gas to flow into the intermediate compartment 48 and thence through the coupling tube 26 to the engine. There remains to be considered the functioning of the regulator as it meters the flow of fuel, independently of the fuel supply pressure, to pass relatively smaller amounts when the engine is idling than when it is running at full speed. This not only insures smooth engine operation but also avoids waste of fuel.

It can be seen that the valves 64 and 90 constitute two serially related regulating valves, with the upper valve 64 serving the additional capacity of an on-off valve, as already explained. The regulating action of each valve is a function of the pressure drop thereacross when gas is flowing. In turn, the pressure drop will be a function of flow area, which depends in each case on the relative positions of the valve and its associated valve body.

The body 58 of the valve 64 is supported by the lower diaphragm 42, so its position relative to the valve 64 will be determined partly by the position of lower diaphragm 42. Valve 64 can only be opened by contact between the stem 66 and the upper diaphragm plate 68. Therefore, the flow area around the upper valve 64 during operation will depend on the relative positions of both diaphragms 42, 44. However, movement of either diaphragm will not per se appreciably affect the position of the other diaphragm, as the spring 70 is only a light closing spring and will not transmit sufficient force from one diaphragm to the other to have any appreciable effect on their relative positions.

The flow area around the valve 90 will depend on the position of the diaphragm 42, because movement of the diaphragm will be transmitted through the rod 72 to the stem 88. The diaphragm position, in turn, is influenced by a number of forces. Those of principal importance are the force exerted by the weight 78 (or by the spring 80), and the resultant of the pressures acting on the upper and lower faces of the diaphragm. The weight 78 (or spring 80) balances the major part of the relatively high pressure in the lower compartment 46 to avoid a large unbalance in the forces on the diaphragm 42. Another minor force on the underface of the diaphragm 42, small enough to be neglected, is that exerted by the valve stem 88, which combines the force of the valve spring 96 and the gas pressure acting on the enlarged portion 90 of the stem.

For a starting point, it can be assumed that the pressure in the chamber 48 is atmospheric pressure, or 14.7 p. s. i., so that valve 64 is closed. It can also be assumed that the weight of the body 78 is such that the body 78 exerts gravitational effect on the diaphragm 42 of, say, 5 p. s. i. Accordingly, the total downward force on the diaphragm 42 will be 19.7 p. s. i., and the valve 90 will remain open until the pressure in chamber 46 builds up to 19.7 p. s. i., at which time valve 90 will close.

Now assume that the pressure in chamber 48 drops to, say 14 p. s. i. Valve 64 will open, permitting some gas to flow out of chamber 46 into chamber 48. As soon as this happens, the pressure in chamber 46 must drop, and as soon as it goes below 19 p. s. i. (the pressure in the chamber 48 plus the effect of the body 78), the diaphragm 42 must flex downwardly, opening valve 90. It will be understood that it is difficult to measure these conditions accurately because, when the engine is operating, the pressure in the chamber 48 fluctuates every cycle. Nevertheless, it can be seen that a decrease in pressure in chamber 48 must result in gas flow out of chamber 46, which ultimately must lead to downward deflection of the diaphragm 42 to open the valve 90. This will lead to a set of conditions in which gas is entering and leaving chambers 46 and 48 at the same rates.

Now assume that gas is flowing steadily through the regulator under such steady state conditions. These might be, say, 14.5 p. s. i. pressure in chamber 48 (which would give 19.5 p. s. i. acting downward on the diaphragm 42), and 19 p. s. i. absolute pressure in chamber 46, which would make the pressure drop across the valve 64 four and one-half pounds. Now suppose the pressure drops to, say, 13.5 in chamber 48. The first tendency would be for the upper diaphragm 44 to move downwardly, and for the lower diaphragm 42 to move upwardly. Both of these movements would have the effect of increasing the opening of valve 64, which would decrease the pressure drop across this valve. If this decrease in pressure drop is only slightly greater than the decrease in pressure in chamber 48, it is evident that the pressure in chamber 46 will decrease more than did the pressure in chamber 48. In turn, this will force the diaphragm 42 to move downwardly, permitting more gas flow through the valve 90 to meet the increased demand.

The entire operation can be viewed in a slightly different way. Starting with both valves 64 and 90 closed, any decrease in pressure in chamber 48 will open valve 64. Once this valve opens, gas will flow from chamber 46 into chamber 48. Continued flow of gas from chamber 48 must inevitably lead to opening of valve 90, because the pressure in this chamber 46 will always start out at a higher value than the pressure in chamber 48 (by an amount determined by the weight of the body 78). In other words, the outflow from chamber 48 must always be made up by an equal inflow to chamber 46 from the bottle. If outflow exceeds inflow, the pressure in chamber 46 must drop, causing the diaphragm 42 to move downwardly to open valve 90 and increase inflow. If inflow exceeds outflow, the pressure in chamber 46 must increase, moving diaphragm 42 upwardly and thereby closing valve 90 to decrease the inflow.

The foregoing is an attempt to explain the operation on the basis of steady gas flow. Actually, in engine operation, the rapid fluctuations in engine manifold pressure which accompany each stroke or cycle probably will cause the valves 64 and 90 to open and close rapidly. However, the same operation outlined above must, on the average, hold true, because valve 90 must always open enough, and just enough, to replenish the reservoir chamber 46 in order to have sufficient pressure in this chamber to ultimately close valve 90.

The action of the regulator in compensating for changes in bottle pressure can be explained as follows:

An increase in bottle pressure will tend to increase the pressure in chamber 46 until something occurs to change the flow area around (pressure drop across) the valve 90. But, such an increase in pressure in chamber 48 will move diaphragm 42 upward slightly, thereby tending to close valve 90 and to increase the pressure drop across this valve.

Upward movement of the diaphragm 42 will raise the valve body 58, tending to open valve 64 slightly which would reduce the pressure drop across this valve. Such a reduction in pressure drop will tend to reduce the pressure in chamber 46, which is the opposite of the original

effect due to the increased bottle pressure. Thus, the diaphragm 42 will finally reach a position at which the new bottle pressure will be distributed properly across the two valves 64, 90 to maintain proper flow at the new bottle pressure. In this connection, it should be kept in mind that there is a very large pressure drop across the valve 90 under any circumstances (of the order of 100 p. s. i.), so that changes in bottle pressure will actually result in only very small pressure changes, in pounds, in chamber 46.

When the engine is running, the (negative) pressure in the carburetor inlet port 27 will determine the rate at which gas will flow through the regulator to the engine. As this pressure at the inlet port 27 becomes more negative, more gas will flow through the regulator. Increased gas flow will tend to increase the pressure drop across the regulating valve 90. However, such an increase in pressure drop will tend to decrease the pressure in the lowermost chamber 46 which will tend to move the lower diaphragm 42 downwardly. Such movement will open the valve 90 further, thereby counteracting the abovementioned tendency toward increased pressure drop across the valve 90. Thus, the pressure in the lowermost chamber 46 will remain substantially constant, because the regulating valve 90 will be adjusted by motion of the diaphragm 42 to compensate for pressure changes induced by bottle pressure changes or by changes in the fuel supply rate.

In terms of engine operation, as the carburetor butterfly valve 18 is opened to speed up the engine or closed to throttle it down, the negative pressure in the inlet port 27 will increase and decrease correspondingly. These pressure changes will react through the regulator in the manner just explained to vary the gas flow as required to supply the correct amount of fuel to the engine.

One transient condition that may be mentioned is that accompanying acceleration of the engine.

When the engine is accelerated rapidly by suddenly opening the butterfly valve 18, there will be a sudden increase in the negative pressure at the port 27. Even though the air flow to the engine will not increase instantly to produce any substantial increase in the pressure drop across the restrictor 28, the opening of the butterfly valve will communicate the relatively high vacuum in the intake manifold 16 directly with the upstream side of the carburetor. This sudden increase in negative pressure, transmitted to the intermediate compartment 48 of the housing, would cause the lower diaphragm to move upwardly but for the inertia of the weight 78 (or of the spring 80) which will prevent any sudden change in the position of the diaphragm 42. Therefore, the flow area around the pressure regulating valve 90 will not change appreciably. However, the sudden demand for increased fuel will be satisfied from the relatively large quantity of fuel stored in the intermediate housing compartment 48. This gives a relatively rich air-fuel mixture before the air flow to the engine has increased appreciably, which is ideal for smooth acceleration. Ultimately, as the flow of gas past the regulating valve 90 increases due to the increased demanded, the diaphragm 42 will adjust the valve 90 as already explained to maintain the proper flow of fuel.

An important feature of the apparatus shown in Figure 2 is the use of the bottle valve 90 as the regulating valve. Over a period of time, this valve would be subject to considerable wear if not replaced, and unless made of very durable material might gradually upset the regulating action. However, as a new valve is always supplied with each bottle of fuel, this problem is avoided.

Of course, for use with fuel containers in which the bottle valve is not suitable for use as a regulating valve, such valve can be incorporated in the regulator assembly. This is illustrated in Figure 5, wherein there is shown a regulator embodying the invention and in which the actuating rod 72 contacts the stem 100 of a valve 102 located in the guide tube 74. In this case, the guide tube 74 is made with a slightly smaller inside diameter so that its lower end will contact and depress the stem 88 of the bottle valve (not shown in Figure 5) to open the bottle valve a fixed amount when the bottle is screwed into the socket 32. In operation, the valve 102 in Figure 5 functions in precisely the same manner as the bottle valve 90 in the Figure 2 assembly.

I claim:

1. Apparatus for supplying gaseous fuel from a container of pressurized gas to a four-stroke-cycle internal combustion engine of the type having an air-fuel intake system including damper means for controlling the flow of air through said system and a restrictor upstream of said damper, said apparatus comprising a fuel-flow regulator including a housing, first and second flexible diaphragms extending across and dividing the space inside said housing into first, second and third compartments, said first diaphragm separating said first and second compartments and said second diaphragm separating said second and third compartments, means defining a passage for conducting gas from said container to said first housing compartment, valve means in said passage coupled to said first diaphragm for controlling the flow of gas through said passage in accordance with the position of said first diaphragm, means defining a second passage communicating between said first and said second compartment, valve means in said second passage coupled to said second diaphragm for opening and closing said second passage in response to movement of said second diaphragm, a tube communicating with said second compartment, and means for coupling said tube to said intake system at a point intermediate said damper means and said restrictor, said housing having an opening therein communicating said third compartment with atmosphere.

2. In an apparatus for supplying gaseous fuel from a container of pressurized gas to a four-stroke-cycle internal combustion engine, said engine including an air-fuel intake system having an air flow control valve for controlling the flow of air through said system and a restrictor upstream of said valve, said container being of the type adapted to be attached to a gas-utilization device and having a gas-outlet passageway containing a spring-loaded valve normally closing said passageway when said container is detached, said valve having an actuating stem exposed in said passageway for opening said valve upon depression of said stem, the improvement comprising a housing, a flexible diaphragm extending across and dividing the space inside said housing into two compartments, means on said housing for assembling said housing to said container with one of said compartments communicating with said passageway, a rod extending from one face of said diaphragm through said one compartment and through said assembly means so as to contact said valve stem upon attachment of said housing to said container, a spring supported in said housing in the other of said compartments and engaging the other face of said diaphragm to exert a force against said other diaphragm face, means defining a passageway communicating between said compartments, a tube communicating at one end with said other compartment, means for connecting the other end of said tube to said system at a point between said restrictor and said air flow control valve, a second diaphragm in said housing separating said other compartment from a third compartment, and a valve in said last-named passageway coupled to be opened and closed by movement of said second diaphragm.

3. In an apparatus for supplying gaseous fuel to an internal combustion engine, the improvement comprising a housing, first and second flexible diaphragms extending across and dividing the spaec inside said housing into three compartments which include first and second compartments on opposite sides of said first diaphragm, and said second compartment and a third compartment on opposite sides of said second diaphragm, means including a valve body carried by said first diaphragm defining

a passage communicating between said first and second compartments, a valve in said valve body coupled to said second diaphragm to be opened and closed by movement of said second diaphragm, said third compartment being open to atmosphere, means in said second compartment exerting a force against said first diaphragm urging said first diaphragm toward said first compartment, and a rod extending from said first diaphragm for actuating a flow-control valve.

4. Apparatus for modifying a gasoline-burning, four-stroke-cycle internal combustion engine to operate on gaseous fuel supplied from a container of pressurized gas, said engine having an air intake system comprising a carburetor having an air inlet port and means for controlling the flow of air through said carburetor, said container being of the type having a threaded neck for attachment to a gas-utilization device and having a gas-outlet passageway in said neck with a spring-loaded valve normally closing said passageway when said container is detached, said valve having an actuating stem exposed in said passageway for opening said valve upon depression of said stem, said apparatus comprising a housing, a socket on said housing adapted to screw onto the neck of said container, first and second flexible diaphragms extending across and dividing the space inside said housing into three compartments which include first and second compartments on opposite sides of said first diaphragm and said second and a third compartment on opposite sides of said second diaphragm, means including a valve body carried by said first diaphragm defining a passage communicating between said first and second compartments, a valve in said valve body coupled to said second diaphragm to be opened and closed by movement of said second diaphragm, said third compartment being open to atmosphere, means in said second compartment exerting a force against said first diaphragm urging said first diaphragm toward said first compartment, a rod extending from said first diaphragm through said first compartment and into said socket so as to contact said valve stem upon attachment of said housing to said container, a tube extending from said housing and communicating at its housing end with said second compartment, and means for connecting the other end of said tube to said carburetor at said air inlet port, said last-named means including a restrictor disposable in said air inlet port on the air inlet side of said port.

5. In an apparatus for supplying gaseous fuel to an internal combustion engine, the improvement comprising a housing, first and second flexible diaphragms extending across and dividing the space inside said housing into three compartments which include first and second compartments on opposite sides of said first diaphragm, and said second compartment and a third compartment on opposite sides of said second diaphragm, means defining a passage through said first diaphragm communicating between said first and second compartments, valve means in said passage coupled to said second diaphragm to be opened and closed by movement of said second diaphragm, means in said second compartment exerting a force against said first diaphragm urging said first diaphragm toward said first compartment, and valve actuating means coupled to said first diaphragm for actuating a flow-control valve.

6. The invention defined in claim 5, wherein said means in said second compartment comprises a spring supported in said housing in said second compartment and engaging said first diaphragm.

7. The invention defined in claim 5, wherein said means in said second compartment comprises a weight resting on said first diaphragm.

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