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[54] METHOD AND APPARATUS FOR GAUGING FLUID FLOW

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[58] **Field of Search** ..... 73/118, 3, 407 PR

[56] **References Cited**

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[57] **ABSTRACT**

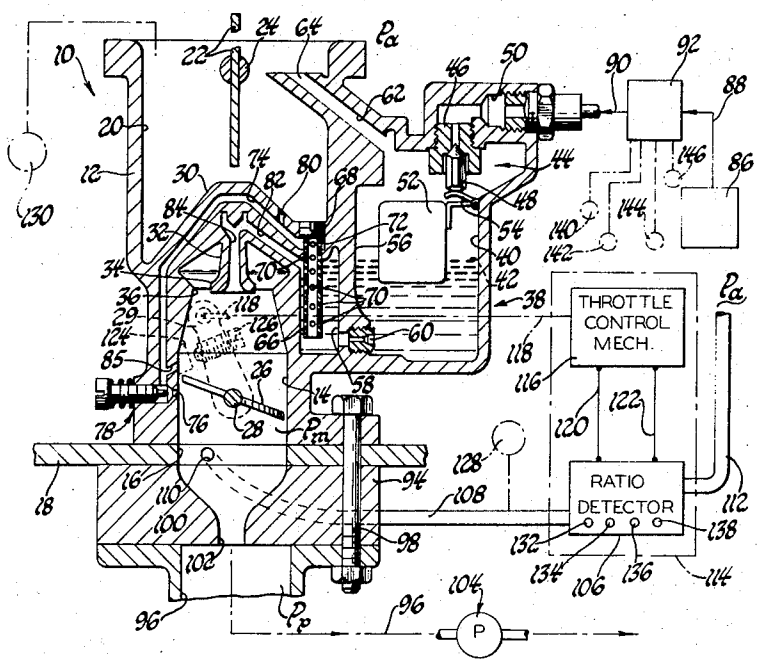
Method

In order to eliminate the effect of variations in barometric pressure, the throttle angle and volume rate of airflow through the induction passage of a second carburetor are matched to the throttle angle and volume rate of airflow through the induction passage of a first carburetor by creating a pressure downstream of the throttle valve of the second carburetor of a value which will produce a measured volume rate of airflow equal to the volume rate of airflow through the induction passage of the first carburetor and which will also, when compared to the then pressure upstream of the throttle valve of the first carburetor, result in a ratio of upstream and downstream pressures equal to the ratio of upstream and downstream pressures as existed across the throttle valve of the first carburetor.

Apparatus

An orifice of predetermined flow capacity is situated at a point downstream of the throttle valve of a test carburetor and the downstream side of the orifice is exposed to a reduced pressure sufficient to cause a predetermined volume rate of airflow therethrough; pressure responsive means responsive to a first pressure between the throttle valve and orifice as well as the ambient pressure upstream of the throttle valve is effective for computing the ratio of said first pressure and said upstream pressure; if the said ratio does not equal a predetermined value the pressure responsive means creates an error signal to an associated control mechanism which causes appropriate rotation of the throttle valve in order to vary the value of said first pressure until said ratio equals said predetermined value.

14 Claims, 3 Drawing Figures



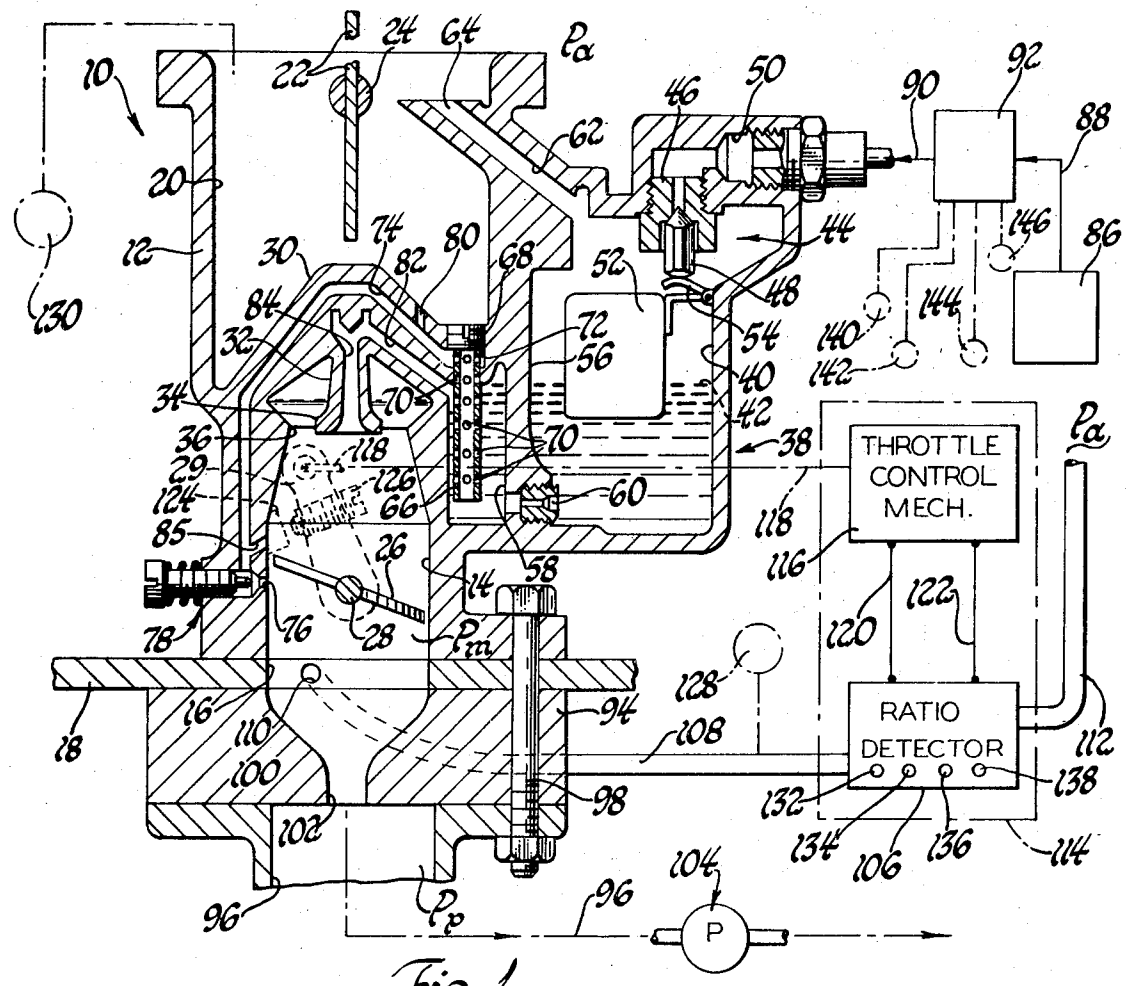


Fig. 1

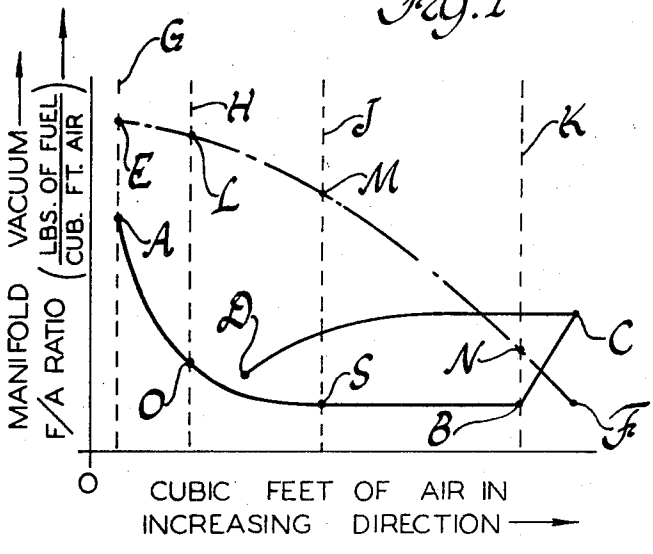


Fig. 2

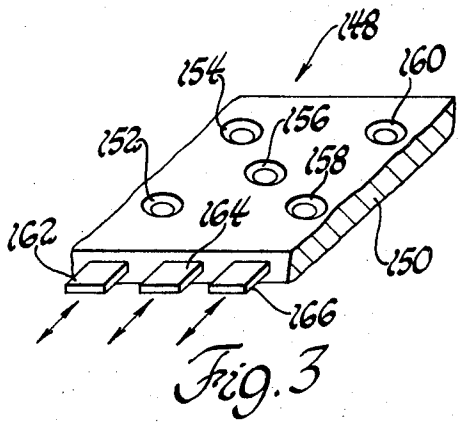


Fig. 3

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METHOD AND APPARATUS FOR GAUGING FLUID FLOW

BACKGROUND OF THE INVENTION

Carburetors for use in combination with internal combustion engines are required to emit fuel to the engine in a predetermined ratio to the air passing through the carburetor and into the engine. However, in those situations where the engine is employed in transportation vehicles the engine speed cannot remain constant and more often than not, the fuel-air ratio has to be capable of a change depending upon whether maximum economy or maximum power of the engine is desired. In order to be assured that a particular carburetor does provide proper fuel-air ratios for varying engine operating conditions the carburetor was first tested under conditions simulating such engine operating conditions.

Generahly, internal combustion engines will produce an emission of unburned hydrocarbons and other pollutents into the atmosphere in proportion to the degree that there is incomplete combustion of the fuel. Accordingly, it can be seen that it becomes important to have the carburetor perform as closely as possible to the ideal fuel-air ratio requirements in order to thereby achieve the greatest possible degree of fuel combustion within the engine during all conditions of engine operation.

Because of recent governmental regulations and a general concern for the elimination and/or reduction of atmospheric pollutents, carburetors have to meet performance specifications, with regard to fuel-air ratios, of exceedingly close tolerances. In order to be assured that each carburetor sold by a carburetor manufacturer meets such specifications, it has been found necessary to actually test each carburetor under simulated engine operating conditions to see if the fuel-air ratio produced by such carburetor meets the related performance specifications.

Such testing, under laboratory conditions, has been done (on what might be regarded as a random sampling basis) with the use of "air boxes" which, as is well known in the art, comprise an enclosed cylindrical air chamber having two relatively slidable cylindrical portions so that an incremental axial movement of one of the cylindrical portions represents a known volume of air. Obviously, such testing structures operated on the principle of displaced air volume.

Such "air box" systems, however, are not a practical device for production testing of carburetors because the time required for testing the carburetor is comparatively long and the cost of building many of such "air boxes" in any one production facility is prohibitive. In employing "air box" systems, it is necessary to totally enclose the carburetor being tested while the airflow is being created through the carburetor. Therefore, it becomes impossible for the test stand operator to perform any adjustment operation on the carburetor while it is being flow checked. The only way that such adjustments can be made is to flow check the carburetor and determine what percentage of error there might be and then uncover the carburetor and make some adjustment which, at best, is an educated approximation. Then the carburetor must again be enclosed and rechecked at that particular point to see if the prior adjustment was either insufficient, sufficient or in excess.

Further, it is known by those skilled in the art that atmospheric pressures are an influencing factor in the testing of carburetors where such testing is not being conducted on the principle of displaced volume. It has been generally accepted that in order to have valid test results, which can be correlated to, for example, a master carburetor, it would be necessary to provide some system for eliminating variations in atmospheric pressure as an influencing factor.

Accordingly, at least one major manufacturer of carburetors has constructed a pressure regulated testing room at a cost of what is estimated to be a million dollars. Such test rooms, of necessity, are costly because of having to provide

structural reinforcements to offset the forces created by differentials between ambient atmospheric pressure externally of the room and the regulated constant pressure within the test room. Further, in order to insure stability of the internal pressure of the room, various air lock chambers must be provided in order to accommodate not only the ingress and egress of personnel but also of the production carburetors to be tested.

In view of the above, it should be apparent that the construction of such pressure-regulated testing rooms is an extremely costly undertaking especially when one realizes that such rooms would have to be provided at each manufacturing facility. Accordingly, if a particular carburetor manufacturer had manufacturing plants at, for example, three locations within the country, at least three such pressure-regulated rooms would have to be constructed.

Contrary to the general belief of those skilled in the art, it has been discovered that such production carburetors can be tested in what can be called the ambient atmosphere with varying atmospheric pressure and still obtain valid test results which may be compared to a master carburetor.

Accordingly, the invention herein disclosed concerns itself with a method of testing carburetors in the ambient atmosphere along with apparatus for carrying out such an inventive method.

SUMMARY OF THE INVENTION

The present invention provides a method of matching the throttle angle opening and volume rate of airflow of a test carburetor to a particular throttle angle opening and corresponding volume rate of airflow of a master carburetor without the necessity of regulating the pressure upstream of the throttle valves, and apparatus for carrying out the inventive method.

According to the invention, a method of matching the flow area of a second variably openable fluid flow restrictor and the volume rate of fluid flow therethrough to a selected flow area of a first variably openable fluid flow restrictor or to a fixed area flow restrictor and the corresponding volume rate of fluid flow through said selected flow area, comprises the steps of determining the volume rate of fluid flow through said selected flow area, determining a first ratio of pressures upstream and downstream of said first variably openable fluid flow restrictor when said restrictor is opened to said selected flow area, establishing and maintaining a volume rate of fluid flow through said second fluid flow restrictor equal to said volume rate of fluid flow through said selected flow area of said first fluid flow restrictor, and adjusting the degree of opening of said second variably openable fluid flow restrictor until a second ratio of pressures upstream and downstream of said second variably openable fluid flow restrictor is equal to said first ratio.

Further, according to the invention, apparatus for establishing a predetermined volume rate of fluid flow through a variable openable fluid flow restrictor and determining the attainment of a preselected effective flow area of said restrictor, comprises first and second conduit means communicating with said fluid flow restrictor and respectively situated upstream and downstream thereof, first means communicating with said second conduit means for determining the attainment of said predetermined volume rate of fluid flow therethrough, a vacuum pump for creating a substantially reduced pressure downstream of said first means for causing said flow of said fluid therethrough, second means for gauging the ambient pressure of said upstream of said restrictor and for gauging the pressure of said fluid in said second conduit means downstream of said restrictor, and third means effective for adjustably opening said fluid flow restrictor until the ratio of said upstream fluid pressure and said downstream fluid pressure is equal to a predetermined ratio which is indicative of the attainment of said preselected effective flow area of said restrictor.

Accordingly, an object of this invention is to provide a method by which variably openable fluid flow restrictors can

be matched, in terms of volume rate of fluid flow therethrough and effective flow area, to previously determined values without the necessity of conducting such operations by poritive displacement of such fluid or by regulating the pressure of the fluid upstream of the restrictor to a constant value.

A further object of this invention is to provide an arrangement or apparatus for practicing the above method.

Other more specific objects and advantages of the invention will become apparent when reference is made to the following detailed description considered in conjunction with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

In the drawings, wherein for purposes of clarity certain details may be omitted:

FIG. 1 illustrates a carburetor (including therein a throttle valve functioning as a variably openable fluid flow restrictor) in cross section, suitably secured to apparatus constructed in accordance with the teachings of the invention;

FIG. 2 is a graph including two separate but related curves one of which represents a characteristic curve of the fuel-air ratio compared to the cubic feet of airflow delivered by a particular carburetor, while the other curve represents the characteristic manifold vacuum generated by an internal combustion engine; and

FIG. 3 is a fragmentary illustration of a modification of a portion of the apparatus disclosed in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in greater detail to the drawings, FIG. 1 illustrates a carburetor **10** having a body **12** with an induction passage **14** formed therethrough and communicating at its lower end with a conduit portion or aperture **16** formed within a base portion **18** of a suitable test stand fixture. Induction passage **14**, at its upper end, is provided with an air inlet portion **20** within which is situated a choke valve **22** mounted on a choke shaft **24** for pivotal rotation therewith. A throttle valve **26** situated within the lower end of induction passage **14** is carried by a throttle shaft **28** for pivotal rotation therewith. As illustrated, the end of throttle shaft **28** is provided with a lever **29** fixedly secured thereto as to thereby enable rotational positioning of the shaft **28** and valve **26**.

The carburetor body **12** is also provided with a bridging portion **30** which also includes a downwardly depending main fuel nozzle **32** which terminates as at **34** generally within the throat of a venturi **36** formed within the induction passage **14**.

A fuel bowl **38**, formed either integrally with or separately from the carburetor body **12**, has a chamber **40** formed therein for the containment of liquid fuel **42**. A fuel inlet valve assembly **44**, comprised of a valve seat member **46** and an axially positionable needle valve member **48**, serves to control the admission of fuel from the fuel bowl inlet conduit **50** to the fuel chamber **40**. As indicated, and as well known in the art, a suitable pivotally secured fuel float **52** has an actuating lever portion **54** engaging the lower end of inlet valve **48** so as to be effective to urge valve member **48** upwardly into engagement with seat **46** to thereby terminate further fuel flow into chamber **40** when the level of the fuel within chamber **40** is sensed to have achieved a predetermined height.

A wall portion **46** serves to generally separate the fuel reservoir chamber **40** from a main fuel well **58** and communication therebetween is controlled by a main metering jet or restriction **60** of a calibrated cross-sectional flow area as is well known in the art. Further, a vent passage or pressure balancing tube **62**, having its upper end **64** exposed to the pressure existing genually within air inlet **20**, has its lower end in communication with the interior of fuel bowl chamber **40** so as to thereby expose one side of the fuel **42** within chamber **40** to the atmospheric pressure, P_a.

Generally immersed within the fuel located in the main well **58** is a downwardly depending idle fuel well tube **66** which may be carried and secured within the carburetor body **12** as by a threaded portion **68**. As can be seen, the tube **66** has a plurality of radially directed passages or apertures **70** formed through the wall thereof in order to thereby provide for a degree of communication between the interior and exterior of the tube **66**. Near the upper end of idle well tube **66**, carburetor body **12** has formed therein a chamber **72** which generally circumscribes the tube **66** and, by means of the radial passageways **70**, communicates with the interior of idle tube **66**. An idle fuel passage **74**, formed through the bridging portion **30**, communicates at its one end with chamber **72** while its other end terminates in an idle fuel discharge port **76** which is located downstream of the throttle valve **26**. An adjustable needle valve assembly **78** is employed for adjustable restricting, if necessary, the rate of flow through discharge port **76**. A calibrated restriction or air bleed passage formed as at **80** serves to, as is well known in the art, create a partial fuel-air mixture to flow through the idle fuel passage **74**.

The main fuel well **58** is also in continuous communication with conduit **82** which communicates at its other end with the main fuel discharge conduit **84** formed within the main nozzle **32**. A second calibrated restriction or air bleed passage (not shown), similar to passage **80**, may be provided for communicating between conduit **82** and the atmosphere in a manner well known in the art.

The general operation of the carburetor, when operatively connected to an internal combustion engine is, briefly, as follows. During curb idle engine operation with the throttle valve **26** nominally closed (as shown), the intake manifold or engine vacuum creates a pressure differential causing fuel to flow from the reservoir or chamber **40** through restriction **60** into main well **58** and through the idle well tube **66** from where, partly mixed with the air from bleed passage **80**, the fuel flows through conduit **74** being discharged into the induction passage **14** through port **76**.

As the throttle valve **26** is rotated towards a more fully opened position, the edge of the throttle valve **26** finally assumes a position somewhat above a transfer port **85** also communicating with conduit **74**. Port **85** is thereby also exposed to the reduced pressure or engine vacuum causing additional quantities of idle fuel to be discharged therethrough and into induction passage **14**.

When the rate of airflow through the induction passage **14** increases sufficiently due to the further opening of the throttle valve **26** and an increase in engine speed, a second vacuum is created at the venturi **36** thereby causing fuel to flow from the main well **58** through conduit **82** and finally discharged from conduit **84** to the induction passage **14**. Accordingly, in view of the preceding it can be seen that the restriction **60**, chamber or well **58**, tube **66**, conduits **74**, **82** and **84** can be considered as generally comprising a fuel supply system.

As generally is illustrated in FIG. **1**, a suitable source or fuel supply means **86** is operatively connected as by conduit means **88** and **90** to the inlet **50** of carburetor **10**. A suitable fuel flow metering means **92** is arranged in series with conduits **88** and **90** in order to measure the rate at which fuel is delivered to chamber **40** which would, in effect, also be the same rate of fuel flow from the carburetor fuel supply system to the induction passage **14**.

A body member **94** may be provided immediately below the support or base **18** so as to be between the base **18** and a conduit **96**. For purposes of illustration, the various components may be held in assembled relationship as by a plurality of screws, one of which is shown at **98**. Body **94** has a passage **100** formed therethrough which, as illustrated, is of a progressively reduced cross-sectional area so as to have a calibrated or sized orifice **102**. In the embodiment shown, orifice **102** is of an effective area which results in the orifice **102** having sonic flow characteristics. Orifice **102** discharges into or communicates with conduit **96** which, as shown, is in communication with suitable vacuum pump **104**.

The area generally below the throttle valve **26** is placed in communication with a pressure ratio detector **106** by means of a conduit **108** which may have its end **110** situated generally

within the orifice **16** of member **18**. A second conduit **112** serves to communicate ambient atmospheric pressure, P_a, to the ratio detector **106**.

The ratio detector **106** may be considered as being within or comprising a portion of an overall computer section **114** which may also include a suitable throttle control mechanism **116** possessing motion transmitting means **118** connectable to the throttle lever **29**. Further, suitable signal transmitting means, such as, for example, electrical conductors **120** and **122** may be employed for interconnecting the ratio detector **106** and the throttle control mechanism **116**. As will become evident, the purpose of such signal transmitting means **120** and **122** is to (at times) convey an error signal to the control mechanism **116**.

The graph of FIG. **2** includes two separate but related curves; that is, the curve represented generally by points A, B, C and D describes that characteristic curve obtained by graphically plotting the fuel-air ratio of the combustible mixture delivered by a particular carburetor compared to the volume rate (cubic feet per minute) of airflow through the carburetor. From this curve it can be seen that when the carburetor throttle valve is moved from its nominally closed or curb idle condition to a more nearly opened condition the fuel-air ratio (F/A) begins to lean-out in accordance with the portion of the curve generally interconnecting points A and B. The portion of the curve interconnecting points B and C represents the action of a power valve assembly, well known in the art, which serves to provide increased fuel flow upon the attainment of predetermined engine loads while the portion of the curve joining points C and D represents the continued influence or action of the power valve as the said predetermined engine load is maintained but airflow is decreased.

The other curve defined generally between extreme points E and F represents the characteristic manifold vacuum generated by the particular engine for which the carburetor is intended when values of such manifold vacuum are plotted against the same volume rate of air flow to the engine.

OPERATION OF INVENTION

Before progressing to the specific description of the operation, it may be best to first provide some general background of the procedure employed for determining whether a particular carburetor is acceptable and, at the same time establish certain assumptions for purpose of description.

Usually a carburetor is manufactured for one particular type and size of engine. Therefore, assuming that the manufacturers of the carburetor and engine are separate entities, the carburetor manufacturer will produce a first particular carburetor structure and deliver it to the engine manufacturer who will then use the carburetor on the particular engine and, in response to testing procedures, establish certain carburetor performance requirements or data which, when graphically plotted result in the two curves of FIG. **2**, nomaly curve E–F and curve A, B, C and D.

The various pertinent adjustments of the said first carburetor are set and locked in place by the engine manufacturer and such carburetor and data are returned to the carburetor manufacturer who then employs the data for calibrating the related test equipment and employs the returned set and locked carburetor as a master carburetor.

In view of the above, it should be apparent that there would be a master carburetor for each particular production-type carburetor intended for a particular engine.

Further, let it be assumed that each production carburetor is to be tested at four different values of airflow as generally depicted by the vertical dash line G, H, J, and K of FIG. **2**. Let it also be assumed that the master carburetor when flow checked, established values which, in turn, determined curve A, O, S, B and that point A represented a nominally closed throttle valve (the position often referred to as, curb idle), point O represented a partly opened throttle valve, point S represented a more fully opened throttle valve while point B represented the point at which the power valve begins to function and the throttle valve is more nearly approaching its wide open position.

For ease of illustration and greater clarity, orifice **102** has been shown as being of a single fixed cross-sectional area. However, for purposes of discussion, let it be further assumed that orifice or passageway **102** is of such a construction as to permit varying of its cross-sectional flow area to any of a number of preselected imperically determined cross-sectional flow areas. In this connection let **102***a*, **102***o*, **102***s* and **102***b* respectively represent the particular imperically determined cross-sectional flow area employed to achieve the volume rate of flow of air as depicted by the values represented by lines G, H, J and K.

During testing, pump **104** is of a capacity sufficient to create a pressure P_p within conduit **96** which, in combination with the variable pressure P_m beneath the throttle valve **26**, causes sonic flow characteristics through orifice **102** regardless of whether the effective flow area thereof is **102***a*, **102***b*, **102***s*, or **102***o*.

Returning now to curve A, O, S, B and the initial use of the master carburetor, it will be remembered that the master carburetor has been set and locked by the engine manufacturer in order to, among other things, establish a particular throttle angle (a degree of opening) when the throttle is in its curb idle position. Further, for purposes of uniformity, the engine and carburetor manufacturers usually agree that at curb idle throttle position the manifold vacuum beneath the throttle will be at for example, a pressure of 19.0 inches of mercury (Hg) and at wide open throttle the manifold vacuum will be 1.50 inches of mercury (Hg).

Accordingly, knowing such data, the master carburetor may be secured to the test stand in the manner depicted in FIG. **1** with the throttle valve in its curb idle position. Orifice **102** is then, through emperical data, selected to have a flow area of **102***a* which in this case (at curb idle) will result in a flow rate creating a pressure P_m under the throttle valve equal to the said 19.0 inches of mercury as represented by point E of the graph of FIG. **2**. Knowing the effective flow area **102***a* of orifice **102** and knowing that it is flowing sonic permits the ready calculation of the volume rate of airflow while instruments such as illustrated at **92** measure the corresponding rate of fuel flow. Such data then can be employed for calculating the fuel/air ratio (F/A) and such ratio can be plotted against the imperically determined volume rate of airflow to establish point A of the curve of FIG. **2**.

At this time the values of both ambient atmospheric pressure (P_a) and pressure P_m are recorded and the ratio thereof computed. Accordingly, assuming that P_a=30.20 inches Hg and there was a 19.0 inches Hg pressure drop across the throttle would mean that P_m=11.20 inches Hg. Therefore, under such conditions the ratio of P_m/P_a=11.20/30.20=R_a. The numerical value of R_a would be 0.3709. R_a would then be the pressure ratio of the pressures downstream and upstream of the master carburetor throttle valve during curb idle conditions.

Other check points may be arbitrarily selected in terms of volume rate of air flow and such other check points are generally designated by the lines H, J and K. Accordingly, assuming that line H represents a volume rate of airflow of 20.00 cubic feet per minute, for example, orifice **102** is selected to have a flow area of **102***o* which has been previously imperically determined to flow 20.00 cubic feed of air per minute under sonic conditions. Pump **104** is then energized to create pressure P_p which, in turn, creates a variable pressure P_m beneath the throttle valve of the master carburetor. Further, if it is assumed that point L, the intersection of line H and manifold vacuum curve E–F, represents 18.0 inches of Hg, the master carburetor throttle valve will be progressively opened until pressure P_m beneath the throttle meets the requirements; that is with P_a being 30.20 inches of Hg, the throttle valve will be rotated until P_m becomes 12.20 inches of Hg. At this time the rate of fuel flow is determined as from instrument **92** and

the fuel-air ratio (F/A) determined as before and the value thereof plotted against the rate of airflow of line H thereby determining point O, the second check point of the curve A, O, S, B.

As with respect to point A, the values of the ambient atmospheric pressure P_a and variable determinable pressure P_m are recorded and the ratio thereof computed. From the above it can be seen that $P_m/P_a=12.20/30.29=R_o$. The numerical value of R_o would be 0.4040. R_o would then be the pressure ratio of the pressures down stream and upstream of the master carburetor throttle valve when the throttle valve was in a position satisfying the requirements of the second check point or point O of curve A, O, S, B.

The same procedure used for determining point O, as discussed above, would be employed for subsequent points S and B on lines J and K, respectively, with such line J and K again representing, for example, arbitrarily selected volume rates of airflow.

When a production carburetor such as carburetor **10** is secured to the test stand **18** for qualifying tests, it should be apparent that, generally, no problems would be encountered if testing procedures in accordance with the prior art were employed if the barometric or ambient atmospheric pressure existing at the time that the master carburetor was flow checked. However, as has been previously stated, barometric pressure often changes and such changes give rise to errors when carburetors are tested in accordance with the prior art which bases its testing philosophy on creating predetermined pressure drops across the throttle valve at every check point.

Now it should be remembered that curve A, O, S, B represents the acceptable or ideal performance is achieved by the master carburetor.

Once the test carburetor **10** is properly mounted and the various connections are made, the carburetor **10** is ready to be tested at its first check point, namely, to see if it performs so as to also achieve point A of the FIG. **2** graph. Accordingly, for the first check point, orifice **102** is selected to have the same area **102***a* as was employed in the flow testing of the master carburetor. This then establishes the fact that the velocity, and therefore the volume rate of flow through orifice **102** must be the same as that established during flowing of the master.

Vacuum pump **104** is energized causing pressure P_p which, in turn, creates the variable pressure P_m posterior to the throttle valve **26**. Now, for purposes of illustration, let it be assumed that the ambient atmospheric pressure, P_a, has changed from 30.20 inches Hg (as when the master carburetor was flowed) to 28.20 inches of Hg. Therefore, according to the invention, throttle valve **26** (as well as the throttle lever **29** operatively secured thereto for rotation therewith) is rotated until pressure P_m becomes a value which will result in a ratio R^1_a, with the then existing atmospheric pressure P_a, equal to the value of R_a. In other words, $R^1_a=R_a=11.20/30.20=P_m/28.20$. Solving for the new P_m it can be seen that in order for R^1_a to equal R_a, P_m must now be equal to 10.46 inches of Hg. When P_m reaches the value of 10.46 inches of Hg, the throttle stop screw **126** illustrated as being threadably carried by the lever **29** for movement therewith, is axially adjusted as to abut against a suitable fixed abutment portion **124** which may be formed externally of and carried by the carburetor body **12**.

At this time, the actual volume rate of airflow through the carburetor induction passage **14** is exactly the same as the volume rate of airflow through the induction passage of the master carburetor when it was flowed for point A. Also, it has been discovered that at this time the relative angle of the throttle valve **26** of the test carburetor is exactly the same as the same relative angle of the throttle valve of the master carburetor when it was being flowed at point A.

Accordingly, having established both throttle angle and volume rate of airflow to be the same, it now becomes a matter of merely determining the rate of fuel flow as from instrument **92** in order to thereby compute the fuel-air ratio (F/A) and see if it coincides with or is within defined acceptable limits of point A of the FIG. **2** graph. If at this time the rate of fuel is determined to be other than that within prescribed limits, the operator may adjust the idle fuel discharge screw **78** in order to thereby cause the rate of fuel flow to be within such prescribed limits at curb-idle conditions.

In order to flow check test carburetor **10** at the second check point as indicated generally by line H of FIG. **2**, orifice **102** is changed to have an effective area of **102***o* as employed with the master carburetor when it was flowed at the same second check point.

If it is now assumed that for some reason ambient atmospheric pressure P_a, has changed to 28.00 inches of Hg, throttle valve **26** will be rotated in the opening direction until P_m becomes a value which will result in a ratio R^1_o, with the then existing atmospheric pressure P_a, equal to the value of R_o. In other words, $R^1_o=R_o=12.20/30.20=P_m/28.00$. Solving for the new P_m it can be seen that in order for R^1_o to equal R_o, P_m must now be equal to 11.31 inches of Hg. When pressure P_m reaches that value of 11.31 inches of Hg, the throttle valve **26** will have been rotated to assume a position of exactly the same relative angle as that which the throttle valve of the master carburetor assumed when it was flowed at the save checkpoint and, at the same time, the volume rate of airflow through the test carburetor **10** is the same as the volume rate of airflow through the master carburetor when it was flowed at the second check point.

Again, the only thing to be determined at this time is the rate of fuel flow which can be obtained from instrument **92** and employed for computing the fuel-air ratio (F/A) in order to see if such value is coincident with or within defined acceptable limits of point O.

The same procedure as set forth above would be employed for testing the performance of carburetor **10** at each of the subsequent check points.

From the above it can be seen that according to the invention, flow testing of carburetors should be performed in a manner whereby the ratio of pressures upstream and downstream of the throttle valve is the controlling factor and not a predetermined pressure differential across such throttle valve. If this method or procedure of testing is employed then variations in barometric or ambient atmospheric pressures will have no effect whatsoever on the testing procedure or the data obtained thereby and, of course, this obviates the necessity of constructing extremely expensive pressure regulated testing rooms as suggested by the prior art.

It should be apparent that the various pressures, such as P_m and P_a, can be visually observed from and determined by suitable gauges as illustrated in phantom line at **128** and **130** and that the throttle valve **26** can be rotated by manual actuation of the throttle lever **29**. However, it is contemplated that in actual use where production quotas require rapid testing of carburetors it would be desirable to provide facilities which eliminate the need for the operator to either manually position the throttle valve or to make any mathematical computations.

Therefore, it is contemplated that the inventive method disclosed herein, may be practiced by employing a computer as depicted at **114**. For example, if four checkpoints were desired, the ratio detector **106** may be provided with four actuating buttons **132**, **134**, **136**, and **138** respectively corresponding to checkpoints A, O, S, and B. Further, the ratio detector **106**, by means of conduits **108** and **112** would be continually exposed to the variable pressures of P_m and P_a. Additionally, the ratio detector would have suitable means therein for registering the respective pressure ratio values of R_a, R_o, R_s and R_b as determined by the use of the master carburetor in the manner previously described.

The throttle control mechanism **116**, which can be any suitable servo-type mechanism, is operatively connected to the ratio detector **106** by suitable error signal transmitting means **120** and **122**. The output of the throttle control mechanism **116** is, in turn, connected as by suitable motion transmitting means **118** to the throttle lever **29**.

As will be seen, the above arrangement enables the rapid testing of production carburetors. For example, when the test

carburetor **10** is properly mounted, the only thing that the operator must do is press button **132** which actuates the ratio detector **106** into comparing the ratio of pressures P_m and P_a. If this ratio, R^1_a, is of a numerical value other than the established reference value of ratio R_a, is of a numerical value other than the established reference value of ratio R_a, an error signal, plus or minus, is applied via means **120**, **122** to the throttle control mechanism **116** which responds to such error signal by causing rotation of the throttle valve **26** in the appropriate direction. Such rotation of the throttle valve in turn causes a change in the value of pressure P_m and the new value thereof is continually communicated to the ratio detector **106** which, of course, causes the value of ratio R^1_a to correspondingly change. When the numerical value of test carburetor pressure ratio R^1_a finally achieves the value of reference pressure ratio R_a, there is no further error signal resulting in the throttle control mechanism remaining motionless. Suitable precalibrated readout devices, as depicted in phantom line at **140**, **142**, **144** and **146** respectively corresponding to the four assumed checkpoints of A, O, S and B, may be provided in conjunction with the fuel flow gauging means **92** so that the operator can quickly (perhaps visually) determine whether the rate of fuel flow is within prescribed limits at the time that ratio R^1_a equals ratio R_a.

When the test carburetor has been found acceptable at its first checkpoint, the operator needs only to actuate button **134**, corresponding to the second checkpoint, and the ratio detector **106** and throttle control mechanism will again function as previously described in order to have the pressure ratio, R^1_o, of the test carburetor equal the reference pressure ratio, R_o at which time the operator observes the second readout device **142** to determine if the rate of fuel flow is within prescribed limits. In view of the above it can be seen that the ratio detector **106**, signal transmitting means **120**, **122**, throttle control mechanism **116**, motion transmitting means **118**, throttle valve **26**, and conduit **108** in effect constitute a closed loop error detecting system in that the system senses the existing error in terms of pressure ratios and corrects itself in order to eliminate such error.

Orifice **102** has been described as being of a nature permitting the attainment of varying effective flow areas identified, for purposes of discussion as being areas **102***a*, **102***o*, **102***s* and **102***b*. FIG. **3** fragmentarily illustrates one such arrangement which could be substituted for the single shown orifice **102** of FIG. **1**. The orifice arrangement **148** may be comprised of a body **150** having formed therethrough a plurality of orifices **152**, **154**, **156**, **158**, and **160** each of a different effective flow area. Additionally, a plurality of slidably situated platelike valve members **162**, **164**, and **166** are received within body **150** so that, when fully pushed in, as shown, they close all of the apertures. However, selective withdrawal of the plate valve members **162**, **164** and **166** results in a corresponding selective opening of the respective orifices controlled thereby. In this manner it becomes possible to selectively open any combination of orifices in order to obtain the desired total flow area for the particular checkpoint involved.

Throughout the preceding description reference has been made to the use of fuel. Even though the invention came about out of problems involving fuel-air ratios of carburetors, it should be apparent that the invention is not so limited and that the word "fuel" should be interpreted as encompassing not only actual liquid fuel but also, as is usually the case, a liquid having the physical properties and characteristics of gasoline where testing is to be performed in confined quarters in order to thereby eliminate the attendant hazards of using combustible liquids. Further, the term "fuel" should also include other fluids which are to be in some way dispensed in particular relationships to a second flowing medium such as, in the case disclosed, air.

The apparatus herein disclosed for practicing the inventive method has been shown as including a sonic orifice **102** (or orifices of varying effective area such of which produces sonic flow). Even though such sonic orifices have been disclosed it should be made clear that neither the method nor the apparatus for practicing the method, as disclosed herein, is in any way limited to the use of a sonic orifice or sonic orifices. The use of a sonic orifice or orifices is to be clearly understood as representing the preferred arrangement in that such sonic orifices present an advantage in the overall apparatus. That is, in using sonic orifices one knows that the volume rate of flow therethrough never changes regardless of variations in either upstream or downstream pressure as long as sonic conditions still exist.

In view of this disclosure, it should be apparent to those skilled in the art that the sonic orifice or orifices disclosed herein could be replaced, for example, by subsonic orifices and that the flow therethrough could be measured by the pressure differential across the subsonic orifice and the effective flow area of such subsonic orifice. In other words, the pressure downstream of the subsonic orifice could be varied, in a manner well known in the art, until a particular predetermined pressure value was attained indicating that the volume rate of flow through the subsonic orifice was that which was desired for that particular test point.

Further, it is conceivable that no such flow measuring orifices would be necessary for practicing the inventive method. For example, it is possible that the vacuum pump **104**, provided that it were a positive displacement pump so that a particular selected pump speed results in a particular volume fluid flow, could be connected, as by conduit **96**, directly to the induction passage **14** at a point, of course, downstream of throttle valve **26**. In such an arrangement, the effectiveness of the pump **104** could be varied by varying its speed, so that the pressure P_m could be varied by adjustment of the variable restrictor until the desired ratio of pressures (as obtained from, for example, gauges **128** and **130**) is achieved.

In view of the preceding, it should be apparent that the invention herein disclosed and described provides a novel method by with volume rates of fluid flow can be matched as between any two passages or conduits each containing therein variably openable fluid flow restriction means without the necessity of in any way maintaining the fluid pressure upstream of the constriction means of the same value for each of the two conduits being compared.

For example, where it has been previously determined that a first fluid flow restrictor, opened to a first position, provides a desired volume rate of fluid flow therethrough, expressed in volume flow of ambient air, all that is necessary in order to determine if a second fluid flow restrictor, of like design and capacity, will also provide a volume rate of fluid flow which is matched to said desired volume rate of fluid flow, by use of the method and apparatus described herein, is to establish a pressure downstream of the second fluid flow restrictor, when compared to the then existing pressure upstream of the second fluid flow restrictor, that results in a pressure ratio equal to pressure ratio of the downstream and upstream pressures of the first fluid flow restrictor when opened to said first position. When this equality of pressure ratios is attained, then as has been disclosed herein, it is known that: (a) the degree of opening of said first and second variably openable fluid restrictors is the same and (b) the volume rate of fluid flow through each of the fluid restrictors is the same.

Accordingly, the principle or method disclosed herein may be equally well applied to many more types of fluid flow devices incorporating variably openable fluid flow restriction means other than the induction passage and pivotal throttle valve specifically shown herein.

Although only a preferred embodiment of the invention has been disclosed and described, it is apparent that other embodiments and modifications are possible within the spirit and scope of the invention.

We claim:

1. A method of matching the flow area of a second variably openable fluid flow restrictor and the volume rate of fluid flow therethrough to a selected flow area of a first fixed or variably

openable fluid flow restrictor and the corresponding volume rate of fluid flow through said selected flow area, comprising the steps of (a) establishing the volume rate of fluid flow at a location downstream of said first flow restrictor, (b) determining a first ratio of pressures upstream and downstream of said first fluid flow restrictor when said restrictor is at said selected flow area, (c) establishing and maintaining a volume rate of fluid flow at a point downstream of said second fluid flow restrictor equal to said volume rate of fluid flow in step (a) above, and (d) adjusting the degree of opening of said second variably openable fluid flow restrictor until a second ratio of pressures upstream and downstream of said second variably openable fluid flow restrictor is equal to said first ratio.

2. A method according to claim 1 wherein the step of determining the volume rate of fluid flow downstream of said selected flow area is achieved by causing sonic flow of said fluid through a sonic orifice of predetermined effective flow area.

3. A method according to claim 1 wherein the step of maintaining said volume rate of fluid flow downstream of said second fluid flow restrictor is achieved by causing sonic flow of said fluid through sonic orifice means of predetermined effective flow area.

4. A method according to claim 1 wherein the step of establishing the volume rate of fluid flow downstream of said selected flow area is achieved by causing sonic flow of said fluid through sonic orifice means of predetermined effective flow area, and wherein the step of maintaining said volume rate of fluid flow downstream of said second fluid flow restrictor is achieved by causing sonic flow of said fluid through sonic orifice means of an effective flow area equivalent to said predetermined effective flow area.

5. A method according to claim 1 wherein said second variably openable fluid flow restrictor comprises a first variably positionable throttle valve within the induction of a test carburetor, wherein said first variably openable fluid flow restrictor comprises a second variably positionable throttle valve within the induction passage of a master carburetor, wherein said selected flow area is determined by the degree of opening of said second throttle valve in said master carburetor, wherein said fluid comprises atmospheric air, and wherein the step of determining the volume rate of flow of air through said selected flow area is achieved by causing sonic flow of said air through calibrated orifice means at a point downstream of said second throttle valve.

6. Apparatus for establishing a predetermined volume rate of fluid flow through a device including a first conduit having a variably openable fluid flow restrictor and determining the attainment of a preselected effective flow area of the restrictor, said apparatus comprising second conduit means communicating with the first conduit downstream of the fluid flow restrictor, first means communicating with said second conduit means for determining the attainment of said predetermined volume rate of fluid flow therethrough, a vacuum pump of creating a substantially reduced pressure downstream of said first means for causing said flow of said fluid therethrough, second means for gauging the pressure of said fluid in the first conduit means upstream of the restrictor and for gauging the pressure of said fluid in said second conduit means downstream of the restrictor, and third means effective for adjustably opening the fluid flow restrictor until the ratio of said upstream fluid pressure and said downstream fluid pressure is equal to a predetermined ratio which is indicative of the attainment of said preselected effective flow area of the restrictor.

7. Apparatus according to claim 6, wherein said first means comprises calibrated sonic orifice means.

8. Apparatus according to claim 6, wherein said second means comprises means for sensing and detecting the ratio of pressures of said upstream fluid pressure and said downstream fluid pressure and being effective to create in accordance therewith an output error signal indicative of the amount by which said ratio deviates from said predetermined ratio.

9. Apparatus according to claim 8 wherein said third means comprises additional servolike output means operatively connected to the fluid flow restrictor and responsive to said error signal for adjustably opening the fluid flow restrictor until said first mentioned ratio equals said predetermined ratio.

10. Apparatus according to claim 8, wherein said restrictor comprises a rotatable throttle valve disposed within a carburetor induction passage and said third means includes throttle positioning means operatively connected to said throttle valve and responsive to said error signal for rotating said throttle until said detected ratio equals said predetermined ratio.

11. Apparatus according to claim 6, wherein the variably openable fluid flow restrictor comprises a rotatable throttle valve situated within an induction passage of a carburetor for an internal combustion engine, wherein said preselected effective flow area is defined by a predetermined angular position of the throttle valve relative to the induction passage, and wherein the first conduit is a portion of the induction passage, said second conduit means communicating with the induction passage.

12. Apparatus according to claim 6 wherein the variably openable fluid flow restrictor of the device is a rotatable throttle valve situated within an induction passage of a carburetor for an internal combustion engine, the preselected effective flow area being defined by a predetermined angular position of the throttle valve relative to the induction passage, wherein the first conduit means being a portion of the induction passage, said first means comprising calibrated sonic orifice means.

13. Apparatus according to claim 12, wherein said second means comprises pressure sensing means for sensing and detecting the ratio of pressures of said upstream fluid pressure and said downstream fluid pressure and being effective to create in accordance therewith an output error signal indicative of the amount by which said detected ratio deviates from said predetermined ratio.

14. Apparatus according to claim 6, wherein said restrictor comprises a rotatable throttle valve disposed within a carburetor induction passage having a fuel supply thereto, said apparatus including means for indicating the rate of fuel flow to said induction passage when said detected ratio equals said predetermined ratio.

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