United States Patent [19]

Bier

[11] **3,842,814**

[45] **Oct. 22, 1974**

[54] **EXHAUST GAS RECIRCULATION SYSTEM**

[75] Inventor: **Kenneth C. Bier**, Bloomfield Hills, Mich.

[73] Assignee: **Colt Industries Operating Corp.**, New York, N.Y.

[22] Filed: **Dec. 15, 1972**

[21] Appl. No.: **315,346**

[52] **U.S. Cl.** .... **123/119 A**
[51] **Int. Cl.** **F02m 25/06**
[58] **Field of Search** .... 123/119 A

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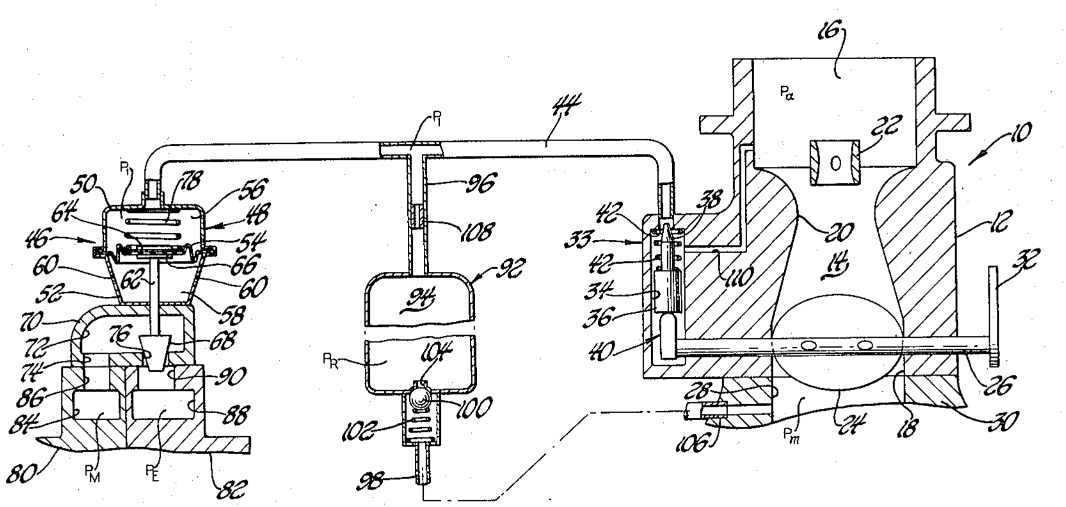
Primary Examiner—Wendell E. Burns

[57] **ABSTRACT**

An exhaust gas recirculation system for recirculating a portion of the engine developed exhaust gases back to the intake of the engine has a variably openable first valve for permitting such exhaust gas recirculation, pressure responsive motor assembly for variably opening the first valve, pressure reservoir means containing a pressure of a relatively low magnitude effective for applying such low pressure to the motor assembly for actuation thereof, and pressure bleeding control valving means positioned in accordance with the position of the throttle valve of an induction device associated with the engine for controllably modifying the magnitude of the relatively low pressure.

12 Claims, 2 Drawing Figures



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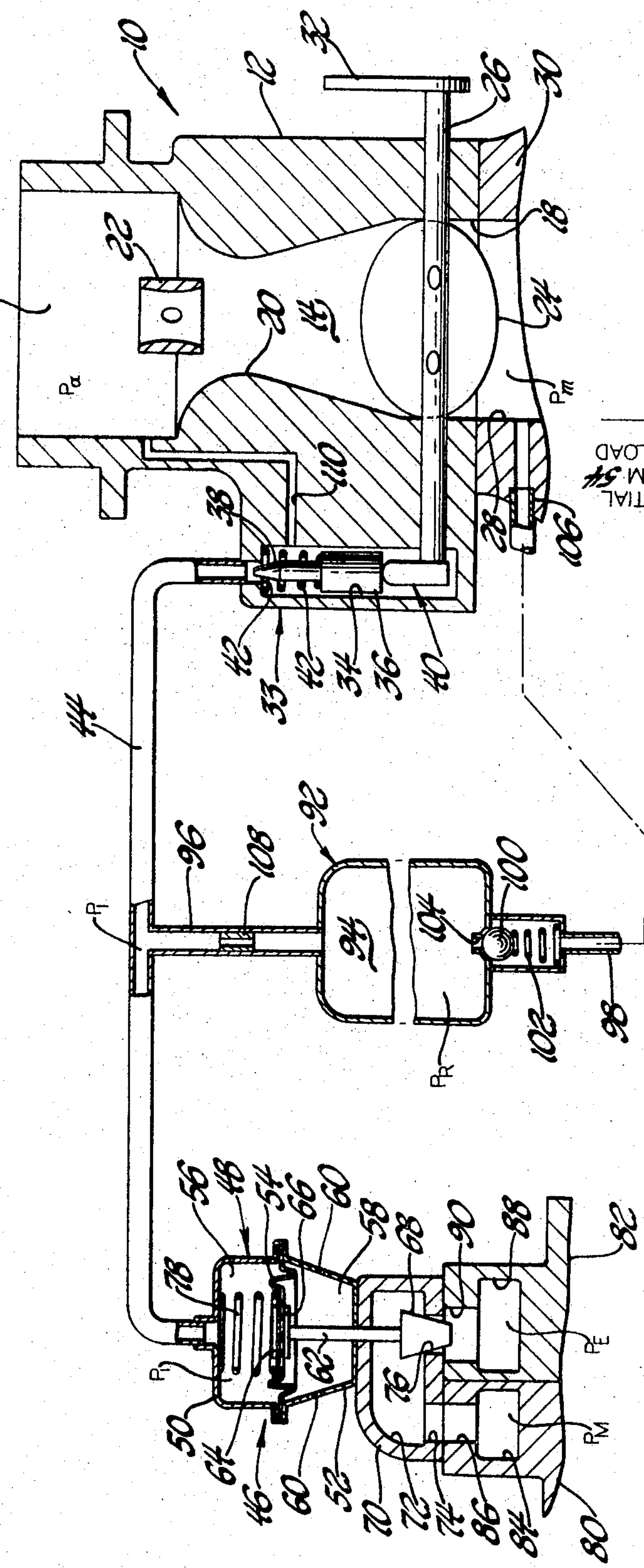

Fig. 1

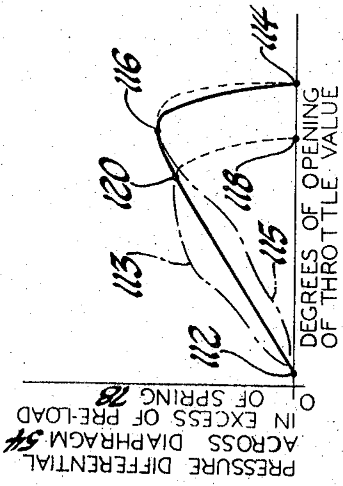

Fig. 2

EXHAUST GAS RECIRCULATION SYSTEM

BACKGROUND OF THE INVENTION

Heretofore it has been well known that one method of reducing the amount of nitrous oxides emitted by an internal combustion engine is to introduce (or recirculate) engine exhaust gases into the engine induction system as, for example, the engine intake manifold. Further, since greater quantities of such nitrous oxides are formed under engine operating conditions of high power output, it is desirable to introduce into the engine a quantity or volume rate of flow of exhaust gas that is proportional to the volume rate of air flow into the engine intake.

Some prior art exhaust recirculation systems recirculated the exhaust gases by introducing them into the venturi section of an associated carburetor. Such a system would meter the flow of exhaust gases proportionately to the rate of air flow; however, the total quantity of flow is limited and the corrosive effects of exhaust gases on the carburetor are undesirable.

Other prior art systems mechanically coupled an exhaust recirculation valve to the throttle valve. Such systems would meter exhaust gas recirculation proportionally but the main disadvantage and safety consideration of such systems resides in the fact the throttle valve may be held open by the recirculation valve becoming stuck in either a partly or completely open position due to contaminates within the exhaust gases.

Accordingly, the invention as herein disclosed and claimed is primarily directed to the solution of the above as well as other attendant problems.

SUMMARY OF THE INVENTION

According to the invention an exhaust recirculation apparatus for recirculating at least a portion of the exhaust gases generated by an engine back to the intake of said engine comprises a vacuum responsive exhaust gas recirculating valve, a source of vacuum for communication with the vacuum responsive valve as to cause said vacuum responsive valve to be responsive to said vacuum, and additional means responsive to opening movement of the throttle valve of an associated engine induction device for modifying magnitude of the vacuum so as to thereby control the response of said vacuum responsive valve.

Various general and 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.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 illustrates an induction device in combination with an exhaust gas recirculation system constructed in accordance with the teachings of the invention; and

FIG. 2 is a graph depicting some characteristic operating curves obtainable by the system of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in greater detail to the drawings, FIG. 1 illustrates a carburetor **10** having body means **12** with

an induction passage **14** formed therethrough having an inlet end **16** and a discharge end **18.** The induction passage **14** may be provided with a venturi **20.** Although the various fuel metering passages and discharge orifices are not illustrated since they form no part of the invention and any of those well known in the art may be employed, a booster-type main fuel discharge nozzle is depicted at **22.**

A throttle valve **24,** carried as by a rotatable throttle shaft **26** for pivotal rotation therewith, is situated within the induction passage **14** for controlling the flow of combustible fuel-air mixture, or air if the discharge **22** is downstream of the valve **24,** therethrough and into intake passage means **28** of an intake manifold **30** of an associated engine. Suitable lever means **32** are provided for variably positioning the throttle valve **24.**

Valving means **33** comprised of a chamber **34** slideably containing a valve member **36,** having a suitably contoured valving surface **38,** which is resiliently urged into seated engagement against a cam member **40** as by a compression spring **42.** Cam **40** is illustrated as being fixedly secured directly to throttle shaft **26.** However, it should be apparent that the cam **40** may equally well be physically separated from throttle shaft **26** and merely operatively connected thereto so as to be positioned in accordance therewith as will become obvious. Generally, as cam **40** is rotated to a particular position, valve member **36** is moved upwardly as to cause metering surface **38** to either seat against or achieve a particular predetermined relationship with respect to a cooperating seating or metering surface **42.**

Conduit means **44,** in communication with chamber **34** via orifice means **42,** communicates with a pressure responsive motor assembly **46** which, as illustrated, may be comprised of a housing assembly **48** having housing section **50** and **52** cooperatively peripherally retaining therebetween a moveable wall or diaphragm **54** so as to define, at opposite sides thereof distinct but variable chambers **56** and **58.** Housing section **52** is provided with suitable venting apertures **60** so as to place chamber **58** in free communication with the ambient atmosphere.

A valve stem **62** suitably secured at one end to diaphragm **54** as by oppositely disposed backing plates **64** and **66** carries, at its other end, a valving member **68.** As generally illustrated, the body or housing assembly **48** is suitably secured to and carried by a related housing or body **70** which defines a passage **72** therein communicating as between ports or orifices **74** and **76** with port **76** being considered as the inlet to passage **72** and port **74** being considered the outlet from passage **72.** A spring **78** situated within chamber **56** normally urges diaphragm **54** and valve member **68** toward seated or closed engagement with a cooperating surface of port **76** as to thereby prevent flow therethrough.

The body **70** is illustrated as being situated atop a first conduit defining member or structure **80** and a second conduit-defining member or structure **82.** Structure **80** may, in fact, be formed integrally with the induction manifold **30**; however, in any event the conduit portion **84** formed within structure **80** is in communication with intake passage **28** of intake manifold **30** so as to thereby have the same pressure existing therein as within the intake manifold **30.** Porting or passage means **86** serves to complete communication between port **74** and conduit **84.**

Structure 82 may, in fact, be formed integrally with the engine exhaust system so as to have the conduit portion 88 define therein in communication with or forming a portion of the exhaust passageway means of such exhaust system. Port 90, located at any suitable place with regard to such exhaust system, is effective for completing communication as between exhaust passage means 88 and inlet port 76.

Generally, during engine operation, when valve member 68 is moved in an opening direction away from port or inlet 76, some portion of the exhaust gases within exhaust conduit means 88 flows through ports 90, 76 into chamber or passage 72 and through outlet 74, port 86 and into intake passage means 84 leading to the associated engine.

A housing 92, defining a chamber 94 which, as will become apparent, serves as a reservoir of relatively low pressure or vacuum, is placed in communication with conduit 44 as by conduit means 96. Additional conduit means 98, which may include a ball check valve 100 and a spring 102, communicates with chamber 94 as through a port 104 in the wall of housing 92. The other end of conduit means 98 is placed in communication with a suitable source of engine or intake manifold vacuum as generally depicted at 106. Suitable restriction means 108 provided generally between chamber 94 and conduit means 44 provides for a control on the rate of flow from conduit 44 to chamber 94. Further, conduit means 110 is provided as between valving chamber 36 and a suitable source of ambient air as, for example, the inlet 17 of the induction passage means 14. Even though illustrated as communicating with inlet 16, it should be apparent that such is done primarily for purposes of disclosing the concept and that conduit means 110 may communicate with any suitable source of ambient atmosphere as well as any other higher pressure source.

OPERATION OF THE INVENTION

Before describing the overall operation of the invention, certain factors should be apparent. That is, before diaphragm 54 can cause valve member 68 to move in the opening direction, the pressure differential across the diaphragm 54 must be sufficient to create a resulting force of a magnitude sufficient to overcome the preload force of spring 78. This, in turn requires an upwardly directed force and, since chamber 58 is vented to the pressure of the ambient atmosphere the only way an upwardly directed force will be created is by the reduction of the pressure within chamber 56. For purposes of reference, the pressure within chamber 56 will be referred to as, P_1; the pressure of the source of ambient atmospheric pressure is identified as, P_a; the pressure within chamber 94 is identified as, P_R; the pressure within intake manifold is identified as, P_M; and the pressure within the exhaust manifold or passage means 88 is identified as, P_E. Further, even though this relationship may not be totally true for all conditions of engine operation, the degree to which pressure P_E may exceed the magnitude of pressure P_a is usually so small that for all practical purposed pressures P_E and P_a may be considered as being equal. During engine operation P_E and P_a will be greater than P_M (with pressure P_M being a variable dependent upon engine load and/or the degree of opening of throttle 24); pressure P_R will be determined by the volumetric capacity of chamber 94, the magnitude of pressure P_M and the degree of flow as between bleed metering surfaces 38 and 42 of the valving assembly 33; and pressure P_1 will be dependent upon the magnitude of P_R and the degree of air bleed by valving assembly 33.

As is generally well known, during engine operation the value of P_M will vary considerably as, for example, from a vacuum reading of about 18.0 inches of Hg as at curb idle (with the throttle valve in a closed or curb idle position), even greater than that on engine deceleration, to a vacuum value of about 1.0 inches of Hg at relatively low engine speed under wide or fully opened throttle valve conditions. However, by employing, in effect, pressure of vacuum reservoir means 92 communicating with pressure P_M, it becomes possible to have a pressure P_R stabilized in magnitude to the degree desired. That is, chamber 94 can be made to be, for all practical purposes, a constant pressure chamber given due consideration for the effective flow area of restriction means 108, the volumetric capacity of chamber 94 and the sufficiency of the sealing characteristics of check valve 100. However, in practicing the invention it is not necessary that chamber 94 be at a constant pressure during engine operation, nor is it necessary that the permissible variation in the magnitude of pressure P_R be small.

Even though all possibilities and combinations of elements and parometers have not been tried, it has, nevertheless, been determined, for the particular embodiments presently contemplated, that the value of pressure P_R may vary, in terms of a vacuum ready, as much as from 5.0 inches of Hg to 14.0 inches of Hg (during the previous referred to range of manifold pressures) and still be suitable for practicing the invention. The said range of 5.0 to 14.0 inches of Hg is, of course, not by way of limitation but rather by way of example.

Now let it be assumed that the engine is started and running at curb-idle conditions. At this time the manifold vacuum, P_M, will be near a maximum value. This is communicated via conduit means 98 to chamber 94 of pressure (vacuum) reservior 92. During curb-idle engine operation, throttle valve 24 is, of course, closed to its curb-idle position. Cam member 40 is so contoured as to result, during such curb-idle engine operation, in valve member 36 being moved sufficiently away from the bleed orifice means 42 as to thereby permit sufficient flow of ambient air through conduit means 110 and into conduit means 44 to cause pressure P_1 to be equal to or approaching the value of pressure P_a.

As the throttle valve 24 is progressively rotated away from its curb idle position and toward a more fully open position cam 40 causes valve 36 to be progressively moved closer to orifice means 42 thereby resulting in orifice means 42 and contoured valving surface 38 combining to restrict the flow of bleed air from passage means 110 into conduit means 44. Because of such restriction to flow of bleed air and because of the flow through restriction means 108 due to reservoir 92 the pressure P_R therein and the manifold pressure P_M, the value of the signal or actuating pressure P_1 diminishes in magnitude causing, as previously explained, diaphragm 54 to start to move upwardly and, in turn, start to move valve member 68 away from orifice and seat 76.

The degree to which valve 68, which is a metering type valve because of the selected contour thereof, opens is, of course, dependent upon the degree to which the magnitude of pressure P_1 has been reduced.

The magnitude of P_1, as previously stated, will depend primarily on the degree to which the flow of bleed air through orifice **42** is restricted by valve member **36** which, in turn, is dependent upon the degree of throttle valve opening.

As exhaust valve **68** is opened, exhaust gases are permitted to flow from exhaust passage means **88**, through ports **90, 76,** through conduit means **72,** ports **74** and **86** and into engine intake passage means. **84.** The degree of such exhaust gas recirculation will be controlled by the degree to which exhaust gas recirculation valve **68** is opened.

Further, since by tailoring the various components, such as the contour of the valve metering surface **38,** contour of cam **40,** effective area of diaphragm **54,** preload and spring rate of spring **78,** the restrictive characteristics of restriction means **108** and the volumetric capacity of reservoir **92,** it has been found possible to obtain any relationship desired as between the rate of opening movement of valve **68** as compared to the rate of opening movement of throttle valve **24,** in the preferred embodiment of the invention such system variables and constants are chosen as to result in the effective flow area, A_E, determined by and between valve **68** and cooperating orifice **76,** increasing linearly and in proportion to the effective flow area, A_C, determined by the degree to which the carburetor throttle valve **24** is opened. Consequently, since the pressure drop of P_E-P_M across the flow area A_E is for all practical purposes equal to the pressure drop P_a-P_M across the flow area A_C, it can be seen that the volume rate of recirculated gas flow will be proportional to the volume rate of flow of fuel-air mixture past throttle valve **24.**

Since it is usually undesireable to provide exhaust gas recirculation during curb-idle engine operation, the valve **68** can be prevented from opening by either the degree of preload force applied by spring **78,** or the degree of bleed air permitted by valving assembly **33** or a combination of both.

Depending on the size and type of engine employed, in some applications it is desireable to have exhaust gas recirculation terminate during only wide open throttle operating conditions while in other applications it is desireable to have such exhaust gas recirculation terminate substantially in advance of when wide open throttle operation is attained, or even to continue some degree of recirculation at wide open throttle.

Referring to FIG. **2,** it can be seen that if point **112** represents curb-idle throttle position and point **114** represents wide open throttle position that the volume rate of exhaust gas flow will increase, linearly, to some maximum point as at **116** after which it quickly reduces in volume rate of flow finally becoming completely terminated as at point **114.** It is apparent that the shape of the portion of the curve between points **116** and **114** may be of any desired characteristic such as, for example, shown by the dash-line between points **116** and **114.** This may be achieved by use of any of the variables within the system including, for example, the contouring of cam **40** so as to cause valving member **36** to move away from cooperating bleed orifice **42** as throttle valve **24** is approaching its wide open position.

It should, of course, be apparent that the invention is not limited to a performance characteristic as represented by the straight line portion between points **112** and **120** of FIG. **2.** That is, by selection of the various constants in the system it is possible to achieve any other desired performance curve such as depicted, for example, by phantom line curves **113** or **115.** Further, it should be apparent that even though a straight line characteristic curve such as that between points **112** and **120** is employed it does not necessarily mean that the percentage of exhaust gas recirculation must be straight line function with regard to the total air flow through induction passage **14,** since such can be modified by tailoring of the contours of, for example, valve **68** and valve seat passage **76.**

Further, as previously stated, in some applications of the invention it may be desireable to terminate exhaust gas recirculation at a throttle opening less than wide open position. If such a point is assumed to be at **118,** then corresponding maximum point might be as at **120** with the dash-line curve between points **118** and **120** be functionally identical to the curve between points **116** and **114.**

It should be apparent that the invention as herein disclosed, provides a system which can be employed to provide exhaust gas recirculation to the associated engine in any desired relationship to engine operation. Also, the invention provides a throttle position responsive exhaust gas recirculation system wherein the exhaust recirculation valve and the throttle valve are not mechanically coupled, thereby eliminating the possibility of the throttle valve being held open by a stuck recirculation valve. Further, it is obvious that by varying the contours of the control valve **36,** or the recirculation valve **68,** or the contour of cam **40** or by varying the spring rates of spring means **78** (including the possibility of providing a secondary spring engageable only after predetermined movement of valve **68**) or the size of restriction means **108,** that a high degree of calibration flexibility may be obtained.

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

1. An exhaust gas recirculation system for an internal combustion engine having first conduit means for conducting from said engine at least part of the exhaust gases generated by said engine and second intake conduit means controlled by a variably openable throttle valve for conducting therethrough a flow of atmospheric air to said engine for supporting the combustion process within said engine, said system comprising passage means interconnecting and communicating between said first and second conduit means, variably positionable valve means for controlling the flow of said exhaust gases from said first conduit means through said passage means and into said second conduit means, vacuum responsive motor means operatively connected to said variably positionable valve means for causing said variably positionable valve means to move in an opening direction in response to an actuating vacuum being communicated to said vacuum responsive motor means, a source of vacuum, third conduit means communicating with said source of vacuum and said vacuum responsive motor means, and variably openable control valve means communicating between a source of ambient pressure and said vacuum responsive motor means, said variably openable control valve means being openable generally in accordance with the degree of opening of said throttle valve, said control valve means being positioned in accordance with the position of said variably openable throttle but free of connection thereto such that sticking of said control valve means in one position could cause sticking of said throttle valve in a corresponding position.

2. An exhaust gas recirculation system according to claim **1** and further comprising cam means operatively connected to said throttle valve for being positioned in accordance with the piston of said throttle valve, and wherein said control valve means is operatively engageable with said cam means for being moved toward and away from a closed position in accordance with the position of said cam means.

3. An exhaust gas recirculation system according to claim **1** and further comprising restriction means situated serially between said source of vacuum and said vacuum responsive motor means so as to at least at times restrict the degree of communication therebetween.

4. An exhaust gas recirculation system according to claim **1** and further comprising fourth conduit means adapted for communication as between said source of vacuum and a source of engine generated vacuum within said intake conduit means downstream of said throttle valve.

5. An exhaust gas recirculation system according to claim **4** wherein the magnitude of said actuating vacuum more nearly approaches the magnitude of said engine generated vacuum within said intake conduit means whenever said control valve means is more nearly closed as to reduce the degree of said bleed as between said source of ambient pressure and said vacuum responsive motor means.

6. An exhaust gas recirculation system according to claim **4** and further comprising check valve means situated generally in said fourth conduit means and serially between said source of vacuum and said intake conduit means.

7. An exhaust gas recirculation system according to claim **1** wherein said vacuum responsive motor means comprises a vacuum responsive diaphragm operatively connected to said variably positionable valve means.

8. An exhaust gas recirculation system according to claim **1** wherein the magnitude of said actuating vacuum more nearly approaches the magnitude of said vacuum within said source of vacuum whenever said control valve means is more nearly closed as to reduce the degree of said bleed as between said source of ambient pressure and said vacuum responsive motor means, and wherein the magnitude of said actuating vacuum more nearly approaches the magnitude of said ambient pressure whenever said control valve means is more nearly opened as to increase the bleed as between said source of ambient pressure and said vacuum responsive motor means.

9. An exhaust gas recirculation system according to claim **1,** wherein variably openable control valve means is openable generally inversely in accordance with the degree of opening of said throttle valve so as to generally further restrict communication between said ambient pressure and said vacuum responsive motor means as said throttle valve is moved toward a more opened position, and wherein said control valve means is effective to at least at times provide a controlled degree of bleed as between said source of ambient pressure and said vacuum responsive motor in order to thereby reduce the magnitude of said vacuum from said source of vacuum and thereby create said atuating vacuum.

10. The combination of an internal combustion engine, an engine intake conduit, an engine exhaust conduit, means for supplying combustion air to said intake conduit, throttle valve means for controlling the flow of said air, a passage for conducting exhaust gas from said exhaust conduit to said intake conduit, valve means for controlling said passage and means including means operated by said throttle valve means for controlling said passage valve so that movement thereof is a function solely of throttle valve movement, said latter means being free of direct mechanical connection between said throttle valve means and said passage valve.

11. The combination of claim **10,** wherein the control by said passage valve controlling means is independent of the specific value of intake conduit vacuum.

12. The combination of claim **10,** wherein said passage valve controlling means is arranged so that return of said throttle valve to closed position is not effected by sticking of said passage valve.

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