United States Patent [19]

Wolgemuth

[11] **3,835,827**

[45] **Sept. 17, 1974**

[54] **EXHAUST AND GAS RECIRCULATING SYSTEM**

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[22] Filed: **Jan. 29, 1973**

[21] Appl. No.: **327,280**

[52] **U.S. Cl.** ..... **123/119 A**

[51] **Int. Cl.** **F02m 25/06**

[58] **Field of Search** ..... 123/119 A

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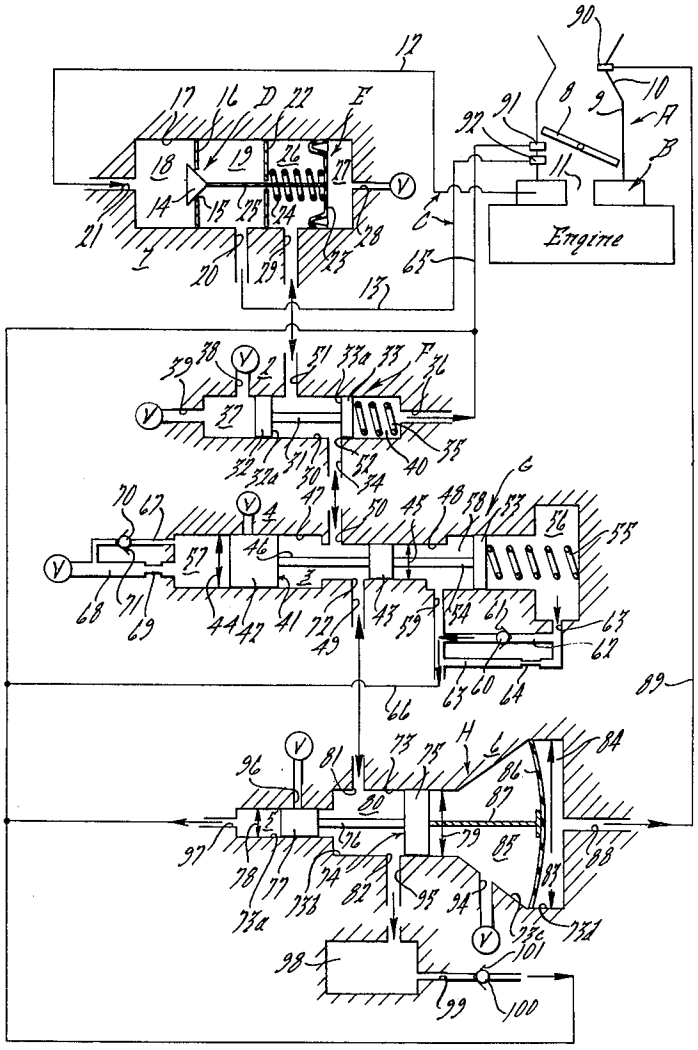
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[57] **ABSTRACT**

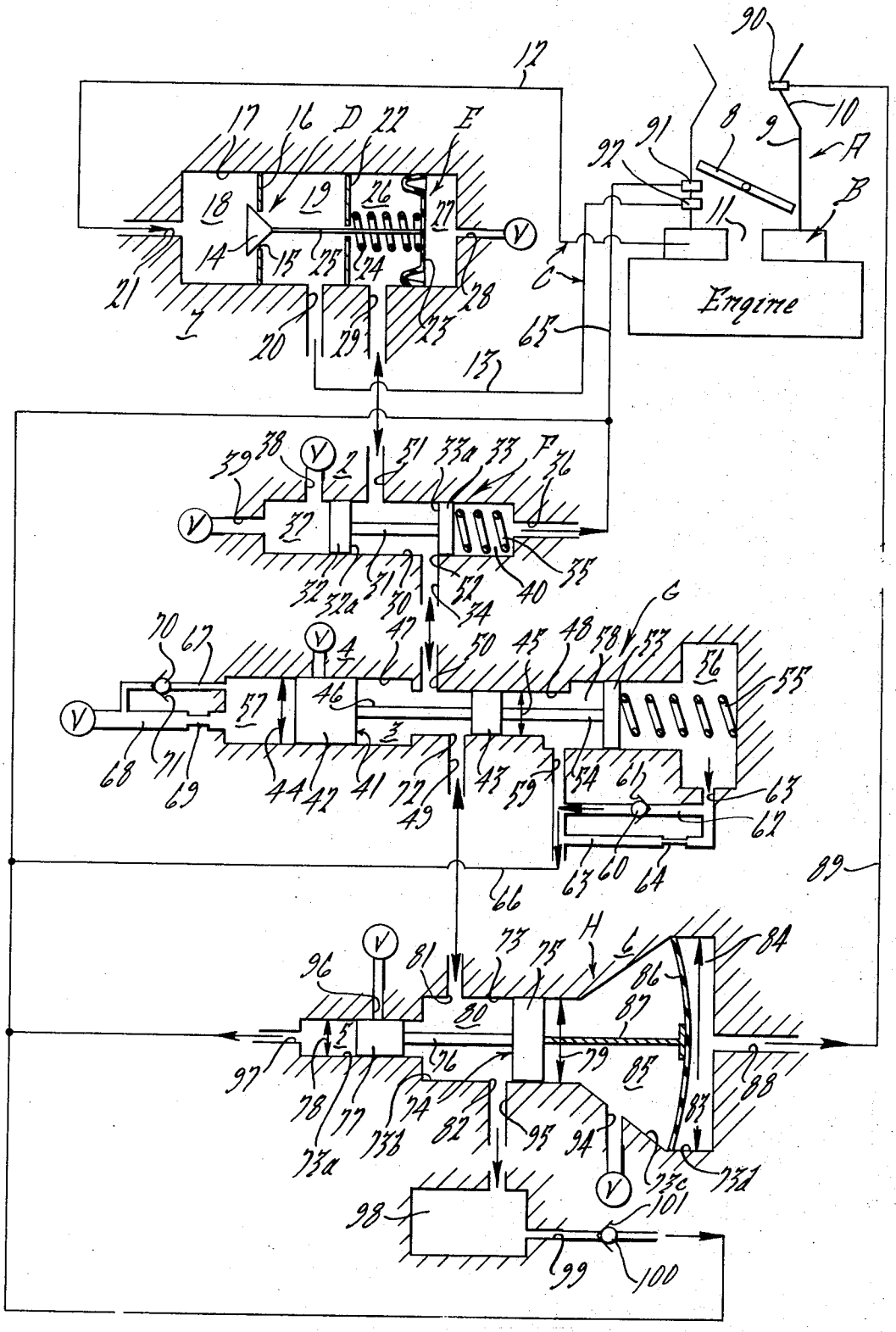
An exhaust gas recirculation system is disclosed employing a primary control valve having a vacuum operated servo mechanism for controlling the admission of recirculating gases. The servo mechanism is operated in response to a modulated vacuum signal derived principally from intake manifold vacuum. Modulation of the vacuum signal is achieved by three control means connected in series, one of which functions in response to a differential between carbureted venturi vacuum and the intake manifold vacuum, another control means operates to prevent communication of the vacuum signal to the servo mechanism during prolonged steady or nearly steady conditions of the engine, yet another control means is effective to prevent communication of the vacuum signal during wide-open throttle conditions of the engine carburetor.

7 Claims, 1 Drawing Figure



PATENTED SEP 17 1974

3,835,827



EXHAUST AND GAS RECIRCULATING SYSTEM

BACKGROUND OF THE INVENTION

Numerous systems have been devised to recycle exhaust gases into the air/fuel induction system of an automotive engine for a variety of purposes among which include:

a. use of the exhaust gases to prewarm and thereby vaporize the incoming air/fuel mixture to facilitate its complete combustion in the combustion zone,
b. recirculation of the exhaust gases to reuse unignited or partially burned portions of the fuel which would otherwise pass out into the exhaust pipe and into the atmosphere, and
c. recirculate exhaust gases for the purpose of reducing oxides of nitrogen emitted from the exhaust system and into the atmosphere. This is brought about by reducing the maximum combustion temperature in consequence of the dilution of the air/fuel mixture by the recycling of exhaust gases.

However, since the load and power demands of the engine change rather considerably over their normal operation, the above goals cannot be easily achieved if consideration is given to driveability and satisfactory engine performance. To this end, the invention is concerned with utilizing control signals which vary the volume and timing of exhaust gas recirculated in conformity with achieving more goals. It is known that the recycling of at least 5 percent and not more than 25 percent of the total exhaust gases through the engines, depending upon the load or power demand, will reduce the combustion temperature to less than 2,200°F. But within this range, the amount recycled at any one moment must be tuned to a variety of engine conditions.

SUMMARY OF THE INVENTION

The primary object of this invention is to provide an exhaust gas recirculation system capable of introducing exhaust gases to the intake manifold system during periods when exhaust gas recirculation will not substantially hinder the normal power operation of the engine and in such modulated quantities that best suit the attainment of lower emissions. To this end, the invention contemplates the control or admission of exhaust gas recirculation in response to a vacuum signal, the signal being modulated primarily in proportion to carburetor venturi vacuum. On and off controls are additionally superimposed over this primary modulation by use of (a) a valve adapted to close on a delayed basis in response to a change in intake manifold vacuum and to remain closed during steady state manifold vacuum conditions, and (b) a valve is adapted to close when wide-open throttle conditions are substantially reached.

One or more combinations of the above controls provide a sensitive variation of exhaust gas recirculation more in tune with the multiple needs of the engine for top performance as well as the emissions criteria.

To provide a constant relationship between recirculation and carbureted air flow, an admitting valve may be contoured to provide a flow area through the throat of the admitting valve which is proportional to the one half power of the modulated vacuum signal; the modulated vacuum signal in turn may be related to venturi vacuum which increases at a rate equal to the second power of the air-flow through the carburetor.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE is a schematic illustration of the exhaust gas recirculation system used in conjunction with a typical internal combustion engine.

DETAILED DESCRIPTION

Referring now to FIG. **1**, a preferred embodiment is illustrated comprising, broadly, an exhaust gas recirculation system adapted to operate with a typical engine having an intake system A and an exhaust manifold B, the intake system further comprising a carburetor having a typical air horn **9** provided with a metering venturi **10** for inducting fuel (not shown) in response to the vacuum created by said metering venturi. A throttle **8** is employed to conventionally control the flow of the fuel and air mixture passing into intake manifold **11** of the engine.

Exhaust gas recirculation is conveyed by a duct or passages C interconnecting the exhaust manifold with the intake manifold; primary valve means D is effective to control the admission of exhaust gases through said duct C. Valve means D is operated in response to a servo mechanism E which has a control element or diaphragm **23** normally biased in one direction to close valve means D and is subject to a modulated vacuum signal to overcome the effect of said bias for opening said valve means. Modulation of said vacuum signal is achieved through a series of control means H, G and F. Means H is effective to control the communication of intake manifold vacuum with the servo mechanism in response to a differential between intake system vacuum obtained at the metering venturi **10** and intake manifold vacuum. Control means F is effective to interrupt normal communication of the modulated vacuum signal to said servo mechanism in response to wide-open throttle conditions of said carburetor. Means G is effective to prevent communication of the modulated vacuum signal with said servo mechanism during prolonged steady state cruising conditions of the engine.

Turning now in more particularity to the components of the system, primary valve means D comprises a rigid valve housing **7** having a cylindrical bore or wall **17** subdivided therein longitudinally into chamber portions **18, 19, 26** and **27** by the respective interposition of flat walls **16, 22** and a diaphragm **23** (forming a control element), all extending transversely across the bore at spaced locations. The wall **16** has an opening **15** therein defining a valve seat; a valve element **14** is movable between opened and closed positions (shown in the semi-open position in FIG. **1**) for said valve seat. The valve element **14** is carried by a valve stem **25** connected with said flexible diaphragm **23** for movement therewith. Inlet **21** chamber portion **18** provides for introducing exhaust gases via conduit **12** from said exhaust manifold; outlet **20** from chamber portion **19** is provided for communicating with the intake manifold **11** of said intake system by way of a conduit **13** connecting with a port **92** positioned below the carburetor throttle **8.**

The servo-mechanism E utilizes a helical spring **24** to bias diaphragm **23** in a direction to bring valve element **14** to a closed position; spring **24** acts between the right hand side of wall **22** and the left hand side of diaphragm **23.** A passage **29** is provided to communicate chamber

portion **26** with the control vacuum signal conveyed from means F, G and H, means H communicating directly with the port **91** of the intake manifold immediately below the throttle of the carburetor. The opposite side of the diaphragm **23** is subjected to pressure in chamber portion **27** which is vented V to atmosphere by way of passage **28.**

Control means H, as indicated, is adapted to provide modulation of intake manifold vacuum in accordance with a signal that rises and falls more closely with the conditions at which the engine can assimulate exhaust gas recirculation. For this purpose the vacuum generated at the primary venturi **10** of the carburetor is utilized; this signal is generally proportional to the second power of the air-flow rate through the air horn **9.** When intake manifold vacuum will be generally high at low speeds of the engine, venturi vacuum will not be low; similarly at high engine speeds, intake manifold vacuum will be generally insignificant whereas venturi vacuum will be available. To employ the venturi vacuum signal, control means H has a housing **6** defining a valve chamber **73** having stepped cylindrical walls **73***a*, **73***b* and **73***d;* walls **73***b* and **73***d* are connected by a tapered wall **73***c*. A spool valve **74** is slidable in chamber **73** and has cylindrical land **77** (having diameter **78**) slidable in intimate contact with the cylindrical wall **73***a;* land **75** (having diameter **79**) is slidable in intimate contact with cylindrical wall **73***b* and diaphragm **86** is connected at the juncture of tapered wall **73***c* and wall **73***d* to define chamber portions **84** and **85.** The lands **77** and **75** are spaced apart, by stem **76,** a distance so that in the position as viewed in FIG. **1,** inlet **95** and outlet **81** to chamber portion **80** are in communication.

Chamber portion **80** is defined by the lands **77** and **75**; inlet **82** is connected to a reservoir **98** by passage **95,** the reservoir in turn is in communication with intake manifold vacuum by way of conduit **65** leading to port **91.** To insure sufficient vacuum for system operation at low intake manifold vacuum levels, an accumulator (in the form of reservoir **98**) is utilized; a check valve **100** acting against seat **101** is employed to preserve the reservoir vacuum. Outlet **81** is ultimately in communication with the servo-mechanism E.

Chamber portion **85** (defined between the land **75** and the diaphragm **86**) is in communication with atmosphere, identified as vent V, by way of passage **94.** Chamber portion **84** (defined between the diaphragm **86** and the end of the chamber) has an inlet **88** in communication (by way of passage **89**) with a port **90** entering into the venturi of the carburetor.

To obtain modulation of the vacuum signal passing through means H, a differential between intake manifold vacuum (acting on the inner surfaces of the spool valve) and venturi vacuum (acting on diaphragm **86**) is employed. Initially, venturi vacuum from passage **89** will flex the diaphragm **86** to the right allowing the spool valve **74** to uncover inlet **82,** thereby admitting the intake manifold vacuum to the chamber portion **80.** Intake manifold vacuum operating against the differential faces of lands **77** and **75** will have a resultant force urging the spool valve to the left and closing inlet **82.** Thus, the resultant intake manifold vacuum force will oppose that of the venturi vacuum operating on the diaphragm; the land areas are chosen so that the forces will be generally in equilibrium or nearly so at mid-range speed conditions for the engine. If engine conditions are such that the venturi vacuum will predominate over the intake manifold vacuum resultant, the spool valve will move further to the right, admitting a larger degree of intake manifold vacuum as the vacuum control signal. This may occur at higher speed conditions. Should the intake manifold vacuum differential predominate, such as at low speeds or idle, the opposite will occur and the valve **74** will be moved to restrict the inlet **82.** When the spool **74** is moved sufficiently to substantially restrict or close the inlet **82,** the vent V will be opened communicating with atmosphere by passage **96.** The vent V cannot be uncovered by over movement of the spool valve to the left because of its attachment to the diaphragm; this prevents a leak to manifold vacuum. All vents, in the various control means, as well as in the primary valve means, are vented to the clean side of the engine air cleaner which is very slightly below atmospheric pressure.

The modulation by means H provides a type of amplification of a weak signal (venturi vacuum) to a relatively strong signal (intake manifold vacuum). At times it may be desirable to construct the apparatus to produce a constant relationship between exhaust gas recirculation and the carbureted air flow through the venturi **10.** To accomplish the latter, intake manifold vacuum in chamber portion **80** (which is our control vacuum) will be modulated further by intake manifold in chamber portion **5** (this manifold vacuum, under most conditions will be slightly different from the control vacuum in chamber **80**). To this end, a passage **97** communicates chamber portion **5** with port **91** of the carburetor. Thus at high manifold vacuum levels, the modulated control vacuum communicated to outlet **81** is reduced from the value which it would normally have at low manifold vacuum levels. This offsets the effect of the vacuum signal on the differential pressure across the primary valve D (namely, the pressure at inlet **21** minus the pressure at the outlet **20**). Thus with high manifold vacuum, control vacuum will be somewhat lowered and the primary valve means D will not be open as far, thereby providing a smaller flow area to compensate for the higher vacuum at inlet **21.**

Proceeding directly to the third control means G (skipping for the moment the second control means F) further modulation of the control vacuum signal is obtained in accordance with transient conditions of the engine. That is to say, the control vacuum will be admitted to permit exhaust gas recirculation during accelerations and short cruises when it is mot desirable to do so. Control means G comprises a housing **4** defining a valve chamber having stepped portions; a first cylindrical wall **47** (having a diameter **44**) is interrupted by a smaller cylindrical wall **48** (having a diameter **45**). An enlarged chamber **56** is defined at the right hand side of the chamber. A spool valve **41** with three lands **42, 43** and **53** is arranged to slidably reciprocate within the chamber portions; land **42** is adapted to slide in intimate relationship with the cylindrical wall **47,** land **43** slides in intimate relationship with cylindrical wall **48,** and the third land **53** (having a diameter similar to land **42**) slides in intimate relationship with the right hand side of the cylindrical wall **47.** The spacing between lands **42** and **43** is arranged to provide a chamber portion **3** and fluid communication between inlet **49** and outlet **50** when the lands are so positioned as in FIG. **1.**

A compression spring **55** is positioned between the termination of the chamber of housing **4** and the right

hand surface of land **53**; spring **55** urges spool valve **41** in a leftward direction causing the edge of the land **43** to move across the edge **82** of inlet **49** and thereby close communication with the outlet. Similarly, the land **42** will uncover a vent allowing the space between the lands to be reduced to substantially atmospheric pressure. Chamber portions **58** and **56** (which are on opposite sides of land **53**) are interconnected by parallel passages **62** and **63**, both of which are commonly in communication with intake manifold vacuum via passage **66** and **65**. Parallel passage **62** contains a check valve adapted to allow intake manifold vacuum to enter chamber portion **56**; the ball element **60** of the check valve will be maintained away from valve seat **61** as the result of vacuum pressure. Parallel passage **63** contains a restriction **64** which acts as a delay mechanism in allowing the transient change in pressure between opposite sides of the restriction.

When intake manifold vacuum is constant, the communication to chamber portions **58** and **56** will impose equal forces on opposite sides of land **53**; spring **55** can thus cause the valve **41** to substantially close. When intake manifold vacuum increases due to deceleration, both the chamber portion **56** and the chamber portion **58** will be further evacuated quickly (check valve **60** will be open) and the valve **41** will still continue to remain substantially closed. However, when manifold vacuum decreases due to an increase in engine acceleration, the check valve **60** will prevent flow from chamber portion **56** through passage **62**. The higher pressure in chamber portion **58** will force the spool valve to the right uncovering the inlet **49**. The spool valve will move slowly due to the restriction **64** with dampens fluid flow to or from chamber portion **56**. When transient condition has expired, the valve **41** will be urged by spring **55** to the left to substantially close the inlet **49** and obtain equilibrium again. The time required to close the inlet **49** can be varied by changing the size of the chambers portions **58** and **56** or changing the size of the restrictor **64**.

Another damper or delay mechanism can be built in at the left hand side of the valve means G by use of a vent passage **68** communicating with chamber portion **57**. A parallel passage **67** is incorporated to also communicate chamber portion **57** with the vent V. In passage **67**, a one way check valve is used, having a ball **70** adapted to seal against seat **71** when vacuum pressure is sufficiently low in chamber portion **57**. A restrictor **69** is incorporated in passage **68** so as to delay flow therethrough. Thus, the time required to close inlet **49** can be additionally extended; when there is a transient change of conditions urging the spool valve **41** to the right or left, the restrictors **69** and **64**, and ball check valves **70** and **60** will cooperate.

The control vacuum signal delivered from the means G intended for the servo-mechanism E can be further controlled by second control means F. Means F is adapted to prevent the admission of the control vacuum signal during wide-open throttle conditions when exhaust gas recirculation is not desired. Means F comprises a housing **2** defining a chamber **30** within which is slidable a spool valve **31** having lands **32** and **33** spaced apart sufficiently to allow communication between an inlet **34** and an outlet **51** for conducting the control vacuum signal. Valve **31** is normally urged to a closed position over inlet **34** by spring **35** residing in chamber portion **40** defined between the right hand land **33** and the end of the chamber. The chamber portion **40** is normally in communication with intake manifold vacuum by way of passage **36**; the chamber portion **37** on the opposite side of the spool valve (between land **32** and the end of the chamber) is in communication with atmosphere by either passage **38** or **39** connected as a vent V. Inlet **34** will be closed by the edge **52** of land **33** when manifold vacuum decreases to such a level that the compression spring acting on the spool valve, moves it sufficiently leftward. In the closed position, one of the vents will be open, particularly through passage **38**. The control vacuum signal acting on the surfaces **32***a* and **33***a* of the respective lands **32** and **33** will offer no differential force urging the spool valve in either direction; therefore the differential between the force of spring **35** and the force of intake manifold vacuum, conveyed by passages **36** and **65**, will determine the position of the spool valve **31**.

The scope of this invention comprehends variations of the series of control means. For example, the system can be used without the transient valve means G if exhaust gas recirculation is desired at steady state cruising conditions. Control means F could be eliminated in conjunction with reservoir **98**; valve means D can then be recalibrated to provide a shut-off at the highest vacuum encountered at wide-open throttle conditions with metering of the recirculation over a small range when above the highest vacuum encountered.

I claim:

1. In an engine having an exhaust manifold, an intake system for inducting air and fuel through a metering venturi into an intake manifold of said engine, an apparatus for recirculating exhaust gases comprising:

a. a duct connecting said intake system and exhaust manifold,

b. valve means interposed in said duct having a first control element normally biased to a closed position and a servo mechanism operable to overcome said bias for variably opening said valve means, said servo mechanism being connected to vacuum from said intake system, and

c. first control means to modulate the connection of vacuum between said intake system and servo mechanism in accordance with pressure at said metering venturi, said first control means being movable in response to a differential pressure between intake manifold vacuum and venturi vacuum to modulate and limit the degree of intake system vacuum communicated to said servo mechanism, said first control means comprising a housing having a bore with stepped portions, a spool valve provided with differential lands slidable in respectively stepped portions of said bore, said bore having an inlet opening in communication with said servo mechanism and an outlet opening in communication with intake manifold vacuum, said outlet opening being arranged so as to be opened or closed by operable movement of said spool valve, the larger of said lands being subject to a force on one side thereof proportional to intake system airflow vacuum tending to move said spool valve to an open position about said outlet opening and the other side of said larger land being subject to the intake manifold vacuum tending to urge said spool valve to a close position.

2. The apparatus as in claim **1**, in which an accumulator is employed to maintain a predetermined level of

intake manifold vacuum for introduction to said first control means during all conditions of operation except when said first control means is closed.

3. The apparatus as in claim **1,** in which the smaller land is subjected to intake manifold vacuum urging said first control means to an open position and thereby maintaining a constant relationship between exhaust gas recirculation and intake system air-flow vacuum even during the closed position of said spool valve.

4. The apparatus as in claim **1,** comprising in combination a third control means effective to prevent communication of said intake manifold vacuum with said servo mechanism during prolonged steady state cruising conditions of said engine.

5. The apparatus as in claim **1,** in which said bias for said servo mechanism is calibrated to provide closure of said valve means at the highest vacuum encountered at wide-open throttle for said engine and said bias being adapted to meter a small amount of exhaust gas recirculation during throttle positions substantially adjacent to wide-open throttle.

6. The apparatus as in claim **1,** in which there is further provided additional control means for controlling the communication of manifold intake vacuum to said servo mechanism, said additional control means being adapted to prevent communication of intake manifold vacuum to said servo mechanism during steady-state conditions of said carburetor air flow.

7. The apparatus as in claim **6,** in which said additional control means comprises a housing having a bore with an inlet thereto in communication with said servo mechanism and an outlet thereof in communication with the inlet to said first control means, a valve element therein normally biased in a closed position preventing flow between said inlet and outlet and a land connecting with said element having opposite sides thereof normally subjected to intake manifold vacuum, and means for delaying the relief of intake manifold vacuum from either side of said land upon a change of intake manifold vacuum so that one side of said land will be effective to overcome said bias and open said second control means according to said predetermined delay.

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