

[54] **PRESSURE TRANSDUCER AND EXHAUST GAS RECIRCULATION CONTROL VALVE USING SAME**

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

[56] **References Cited**

UNITED STATES PATENTS

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3,783,848	1/1974	Ranff et al.	123/119 A
3,799,131	3/1974	Bolton	123/119 A

Primary Examiner—Wendell E. Burns

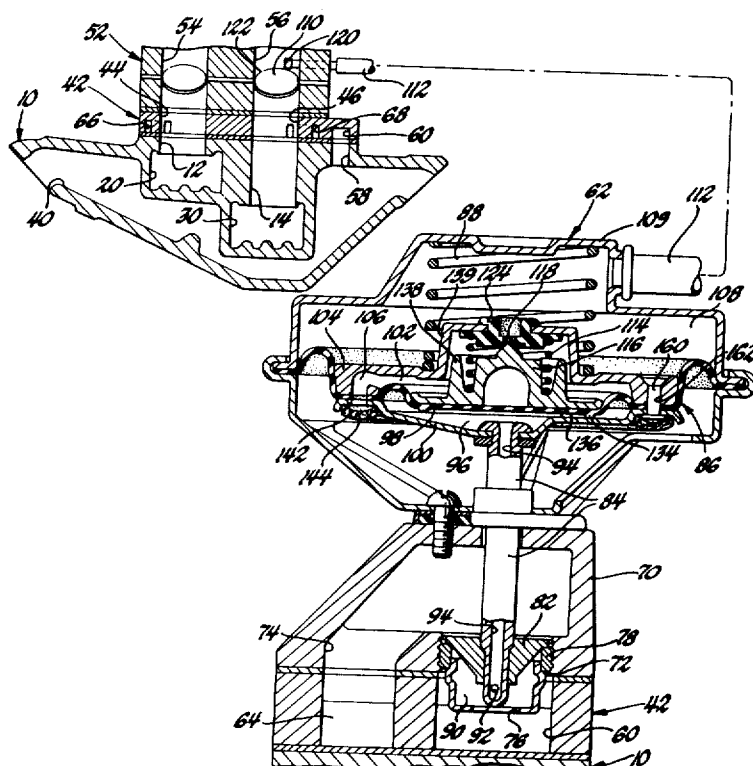
Assistant Examiner—D. Reynolds

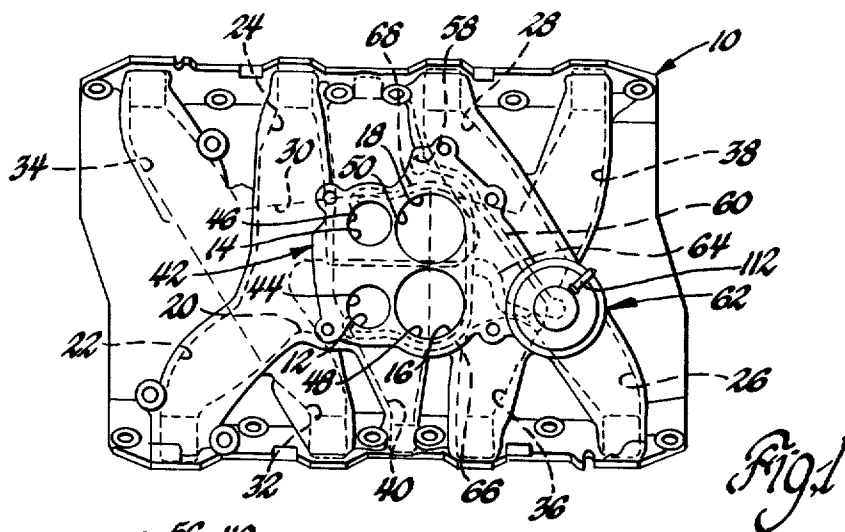
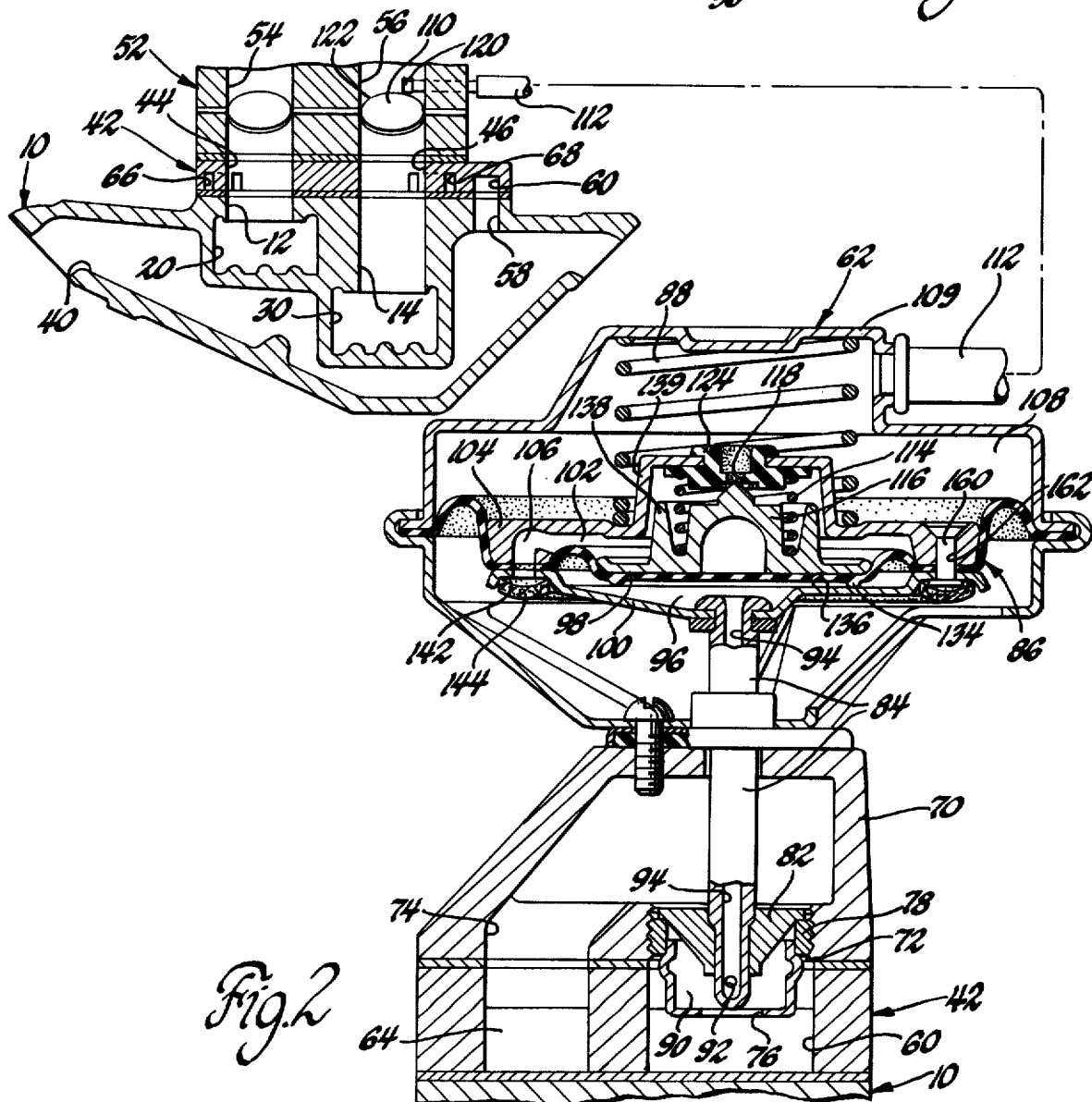
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[57] **ABSTRACT**

A tapered air bleed valve responsive to exhaust back pressure controls the flow of air through an air bleed orifice into a vacuum region to create a signal which controls recirculation of exhaust gases from the intake manifold exhaust crossover passage to the intake manifold induction passages. The bleed orifice has a flexible lip which cooperates with the tapered valve for proper air flow control and which deflects to permit the tapered valve to seat on a larger base.

5 Claims, 5 Drawing Figures





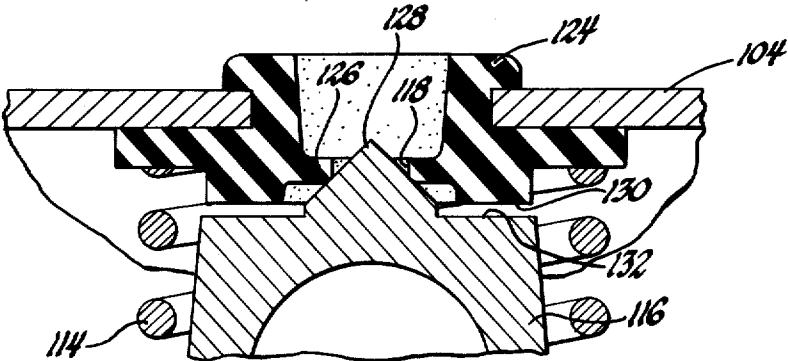


Fig. 3A

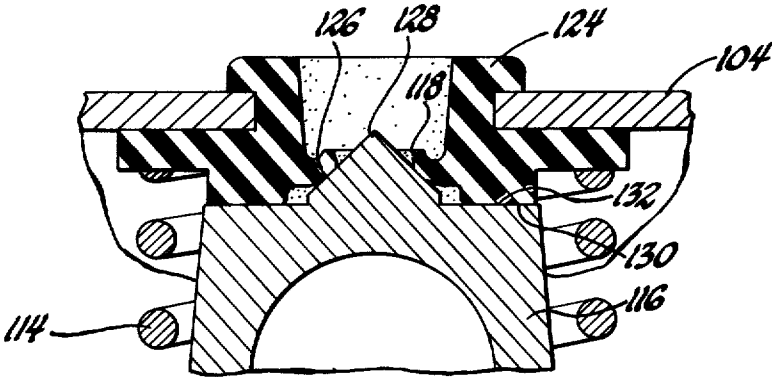


Fig. 3B

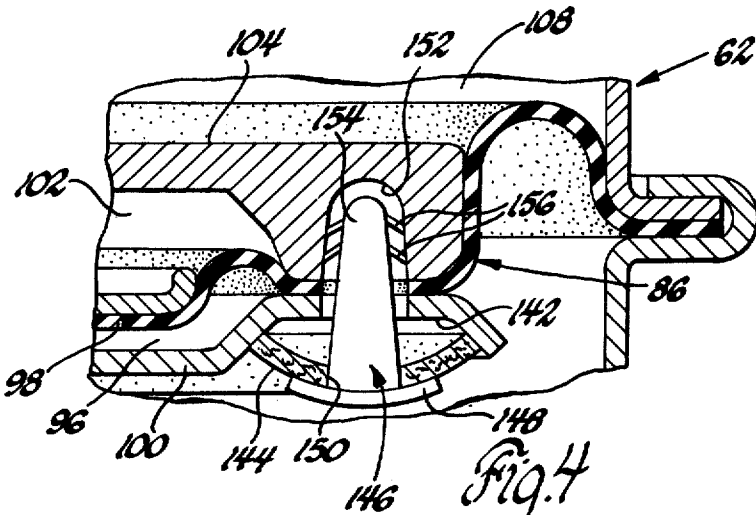


Fig. 4

PRESSURE TRANSDUCER AND EXHAUST GAS RECIRCULATION CONTROL VALVE USING SAME

This invention relates to a novel pressure transducer and to a novel valve assembly using such a pressure transducer for controlling exhaust gas recirculation.

Recirculation of exhaust gases has been developed as a method for inhibiting formation of oxides of nitrogen during the combustion process in an internal combustion engine. In general, it is desired to recirculate the exhaust gases at a rate proportional to the rate at which combustion air flows into the engine, and valves responsive to induction passage vacuum or throttle position have been utilized for this purpose.

It also has been recognized that if exhaust gases were recirculated through an orifice into a region of substantially atmospheric pressure in the engine air induction system, variations in exhaust back pressure would cause the exhaust gas recirculation rate to be proportional to the combustion air flow rate. However, such a system would require that the exhaust gases pass through at least a portion of the carburetor.

This invention provides a novel valve assembly utilizing the exhaust back pressure to recirculate exhaust gases at a rate proportional to air flow and in a manner which avoids recirculation of exhaust gases through the carburetor. In employing this invention, an exhaust gas recirculated passage is provided which extends from the engine exhaust passage to the engine air induction passage at a point downstream of the engine throttle. An orifice is provided in the recirculation passage, and a valve disposed downstream of the orifice is operated to create a zone of substantially constant pressure in the passage irrespective of the wide variations in exhaust back pressure and induction passage vacuum. The rate of recirculation of exhaust gases through the zone thus is proportional to the rate of induction air flow.

In other valve assemblies recently proposed for controlling exhaust gas recirculation in accordance with exhaust back pressure, the diaphragm responsive to back pressure has directly operated the valve pintle to control the flow of exhaust gases. In the design of such a valve assembly, certain limitations are encountered because the back pressure generally is very low. In the valve assembly of this invention, on the other hand, the exhaust gas flow controlling valve pintle is not directly operated by an exhaust back pressure responsive diaphragm; instead, the valve pintle is positioned by a main diaphragm operated by a vacuum control signal, and a pilot diaphragm and bleed valve responsive to exhaust back pressure control that signal by varying an orifice which bleeds air into a region of induction passage vacuum to create the control signal.

A valve assembly of the foregoing description is set forth in commonly assigned U.S. Pat. No. 3,834,366. The valve assembly set forth herein is an embodiment of such which has been improved in several respects as described below. In addition, the valve assembly set forth herein makes use of inventions set forth in commonly assigned U.S. Pat. No. 3,762,334, U.S. Pat. No. 3,799,131, and U.S. Pat. No. 3,783,848. The disclosures of the foregoing are incorporated herein by reference.

Among the improvements provided by this invention is an improved bleed valve and seat structure. Previous structures had a tapered bleed valve member varying

air flow through the bleed orifice. To prevent air flow through the bleed orifice, the bleed valve member engaged the periphery of the bleed orifice. When both the valve member and the orifice member were metallic, the line contact seating which resulted was subject to leakage and wear. When one of the members was formed of an elastomer such as Viton, adequate seating area could be obtained by spring loading sufficient to deform the elastomer, but there was still potential for deterioration due to wear as well as for the valve member to stick or "cork" in the orifice member.

In the improved bleed valve and seat structure provided by this invention, the orifice member has a resilient lip portion cooperating with the tip of the bleed valve to control air flow through the orifice. The lip deflects to permit the base of the bleed valve to engage a flat planar portion on the orifice member. The flexible lip assures adequate seating area between the valve member and the orifice member without requiring loading sufficient to cause coking of the valve member and its deflection permits the seating forces to be absorbed over a large area to prevent wear and resulting deterioration.

This improved transducer structure, here used to convert a fluctuating exhaust pressure signal to a varying exhaust gas recirculation vacuum control signal by regulating an air bleed, also may find utility in other applications where a varying pressure signal is converted to a modified control pressure signal.

Another improvement provided by this invention is an annular paper filter element, arcuate in cross-section, which opens concavely into a channel from which air is supplied to the bleed orifice. The filter element is held in place by a plurality of barbed clips which are received in recesses opening from the channel. This provides an easily assembled and effective mechanism for filtering the air flowing through the bleed orifice.

The details of these as well as other improvements and advantages provided by this invention are set forth in the remainder of the specification and are shown in the drawings, in which:

FIG. 1 is a top plan view of an internal combustion engine inlet manifold having induction and exhaust gas crossover passages, an insert plate having an exhaust gas recirculation passage mounted on the manifold, and the exhaust gas recirculation control valve assembly mounted thereon;

FIG. 2 is a schematic sectional view of the FIG. 1 manifold and spacer plate showing the induction passage plenums and the exhaust crossover passage in the manifold and the exhaust gas recirculation passage in the insert plate together with a carburetor throttle body, and in enlarged detail, the vacuum operated back pressure responsive exhaust gas recirculation control valve assembly;

FIGS. 3A and 3B are fragmentary views of the valve and orifice members, further enlarged to show the operation of the flexible lip portion; and

FIG. 4 is a fragmentary view showing one of the clips securing the filter element.

Referring first to FIGS. 1 and 2, an air induction manifold 10 has a pair of vertical primary riser bores 12 and 14 and a pair of vertical secondary riser bores 16 and 18. Riser bores 12 and 16 open to an upper horizontal plenum 20 connected forwardly (leftwardly as viewed in FIG. 1) to a pair of transverse runners 22 and

24 and connected rearwardly (rightwardly as viewed in FIG. 1) to another pair of transverse runners 26 and 28. Similarly, riser bores 14 and 18 open to a lower horizontal plenum 30 connected forwardly to a pair of transverse runners 32 and 34 and rearwardly to another pair of transverse runners 36 and 38.

An exhaust crossover passage 40 extends transversely from the left-hand side of manifold 10 beneath plenums 20 and 30 and receives a portion of the exhaust gases discharged from the engine combustion chambers.

An insert plate 42 is secured on manifold 10 and has primary riser bores 44 and 46 and secondary riser bores 48 and 50 which meet, respectively, riser bores 12, 14, 16, 18 of manifold 10.

A carburetor 52 is secured on insert plate 42 and has primary throttle bores 54 and 56 which meet, respectively, primary riser bores 44 and 46 of insert plate 42. Carburetor 52 also has secondary throttle bores (not shown) which meet secondary riser bores 48 and 50 of insert plate 42.

A bore 58 in manifold 10 leads upwardly from exhaust crossover passage 40 to the first portion 60 of an exhaust recirculation passage formed in insert plate 42. The first portion 60 of the exhaust recirculation passage leads through a control valve assembly 62 to a second portion 64 of the exhaust recirculation passage. This second portion 64 divides into a pair of branches 66 and 68 which lead to the primary riser bores 44 and 46 in insert plate 42.

It should be appreciated that both portions 60 and 64 of the exhaust recirculation passage may be integrated in manifold 10 rather than in separate insert plate 42.

Valve 62 comprises a valve body 70 having an inlet 72 receiving exhaust gases from first portion 60 of the exhaust recirculation passage and an outlet 74 discharging exhaust gases to second portions 64 of the exhaust recirculation passage. An orifice member 76, disposed across inlet 72, is welded to a valve seat member 78 threadedly secured in inlet 72 in a tamper-proof location. A valve pintle 82 has a conical contour cooperating with valve seat 78 to control the flow of recirculated exhaust gases. Pintle 82 is welded on a hollow valve stem 84 carried by a pressure responsive diaphragm 86 and downwardly biased by a spring 88.

The pressure in the zone 90, defined between orifice member 76 and valve seat 78, is applied through lateral openings 92 and a longitudinal passage 94 formed in stem 84 to a control pressure chamber 96 defined between the central or pilot portion 98 of diaphragm 86 and a dished diaphragm backing member 100. A chamber 102, defined between central portion 98 of diaphragm 86 and another dished diaphragm backing member 104, is maintained at atmospheric pressure by a plurality of annularly spaced openings 106 extending through diaphragm 86 and backing members 100 and 104. The controlled pressure chamber 108 defined over diaphragm 86 and backing member 104 by a cover 109 is subjected to the pressure in the induction passage downstream of throttle 110 by a vacuum hose 112.

In operation, as the control pressure in zone 90 and control pressure chamber 96 drops, central portion 98 of diaphragm 86 is pushed downwardly by a spring 114. An aluminum bleed valve member 116 secured to diaphragm portion 98 then is displaced from an air bleed orifice 118 to admit air from atmospheric pressure

chamber 102 to chamber 108. This increases the controlled pressure or pressure signal in chamber 108, and spring 88 displaces diaphragm 86, stem 84 and valve pintle 82 toward valve seat 80 to reduce recirculation of exhaust gases. Upon an increase in the control pressure in zone 90 and control pressure chamber 96, diaphragm portion 98 moves upwardly against the bias of spring 114 and valve member 116 reduces air flow through orifice 118 into chamber 108. The resulting reduction in the controlled pressure in chamber 108 displaces diaphragm 86, stem 84, and valve pintle 82 upwardly from valve seat 80, thereby increasing recirculation of exhaust gases. In this manner, a constant pressure is maintained in control pressure zone 90 downstream from orifice 76.

The back pressure created in the exhaust passages such as 40 of an internal combustion engine is generally proportional to the square of the rate of combustion air flow through the engine induction passages such as the riser bores, plenums, and runners of manifold 10. The rate of flow of exhaust gases from first portion 60 of the exhaust recirculation passage through an orifice such as 76 into a zone such as 90 of substantially constant pressure is generally proportional to the square root of the exhaust back pressure. Thus the rate at which exhaust gases are recirculated is generally proportional to the rate at which combustion air flows to the engine.

It will be appreciated that, if desired, valves responsive to temperature and other engine or vehicle operating conditions may be disposed in hose 112 to control application of vacuum to chamber 108 and thus to superimpose supplemental control on recirculation of exhaust gases.

It also will be appreciated that valve assembly 62 may be tailored to prevent recirculation of exhaust gases whenever the induction passage vacuum is very low, thus preventing any reduction in power due to charge dilution during wide open throttle operation. In addition, hose 112 may receive the vacuum signal from a port 120 located adjacent and traversed by the upstream edge 122 of a throttle 110, thus preventing recirculation of exhaust gases during closed throttle operation when port 120 senses the substantially atmospheric pressure upstream of throttle 110.

As shown in greater detail in FIG. 3, orifice 118 is formed in an orifice member 124 formed of Viton or a similar resilient material. Member 124 has a resilient lip 126 adapted to engage the tip 128 of bleed valve member 116 and a flat planar seating 130 adapted to engage the base 132 of valve member 116.

It will be appreciated that, over most of the range of pressure in zone 90 and control pressure region 96, the position of tip 128 will vary in orifice 118 to regulate air flow therethrough. When this control pressure reaches a predetermined value, tip 128 will engage lip 126 to prevent additional air flow as shown in FIG. 3A. If lip 126 were not flexible, the force on diaphragm portion 98 and valve member 116 required for sufficient relative deformation of valve member 116 and orifice member 124 to provide adequate sealing area could cause valve member 116 to stick or cork in orifice 118 and repeated engagement of valve member 116 against orifice member 124 could cause wear and deterioration of one or both members. Accordingly, lip 126 flexes upon any further increase in control pressure, as shown in FIG. 3B, permitting valve base portion 132 to engage seating rim 130. Both base portion 132 and rim 130 are

flat planar surfaces which provide adequate area for absorbing the seating forces and limit travel of valve member 116 before tip 128 can become stuck in orifice 118.

It may be noted that an annular bead 134 on the bottom of diaphragm portion 98 engages a flat portion 136 of backing member 100 to limit opening movement of bleed valve 116, to dampen vibration of diaphragm portion 98 against backing member 100, and to maintain diaphragm portion 98 spaced from backing member 100.

It also may be noted that an annular guide 138 surrounds valve member 116 to retain spring 114 and cooperates with a cupped portion 139 of backing member 104 to assure proper orientation of valve member 116 and orifice member 124.

As shown in FIGS. 2 and 4, openings 106 lead from an annular, downwardly concave channel 142 at the edge of backing member 100. An annular paper filter element 144 having an upwardly concave arcuate cross-section is received in channel 142. A plurality of clips 146 (see FIG. 4) having a head portion 148 underlying filter element 144 are received through associated openings 150 in element 144 and extend to recesses 152 formed in one or both of the diaphragm backing members 100 and 104. The stem portions 154 of clips 146 have laterally extending outwardly biased barbs 156 which engage and grip the sides of recesses 152 to prevent dislocation of clips 146 from recesses 152 and thus support and retain filter element 144 in channel 142.

Referring again to FIG. 2, backing members 100 and 104 are clamped about the diaphragm 86 by a plurality of annularly spaced rivets 160 which extend through apertures 162 formed in backing members 100 and 104 and diaphragm 86. Alternatively, rivets 160 could be formed integrally with one of the backing members by a projection which would extend through apertures 162 in the other body.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. For use on an internal combustion engine having an induction passage for air flow to the engine, a throttle in said induction passage for controlling air flow therethrough, and an exhaust passage for exhaust gas flow from the engine, a pressure transducer for converting the variable pressure in said exhaust passage to a variable vacuum signal comprising a reciprocable pressure responsive diaphragm, a first housing member secured on one side of said diaphragm to form an exhaust pressure chamber therebetween, a second housing member secured on the other side of said diaphragm to form an atmospheric pressure chamber therebetween, openings for subjecting said exhaust pressure chamber to the pressure in said exhaust passage and for subjecting said atmospheric pressure chamber to atmospheric pressure, a cover enclosing said other side of said diaphragm and said second housing member and defining a region outside said atmospheric pressure chamber adapted to be subjected to the vacuum in said induction passage downstream of said throttle, said second housing member having an orifice opening from said atmospheric pressure chamber to said region, said diaphragm having a valve member reciprocable therewith, said valve member having a base portion and a tip portion and being associated

with said orifice for controlling air flow from said atmospheric pressure chamber into said region to thereby vary the pressure in said region in accordance with variations in the exhaust passage pressure, and which further comprises an orifice member surrounding said orifice, said orifice member having a resilient lip receiving said tip portion of said valve member and a seating rim receiving said base portion of said valve member after said tip portion has engaged said resilient lip whereby said valve member may seal against said orifice member to prevent air flow into said region without causing said tip portion to stick in said orifice.

2. An exhaust gas recirculation control valve assembly for use on an internal combustion engine having an induction passage for air flow to the engine, a throttle disposed in said induction passage for controlling air flow therethrough, an exhaust passage for exhaust gas flow from the engine, and an exhaust gas recirculation passage having a first portion extending from said exhaust passage and a second portion extending to said induction passage downstream of said throttle, said control valve assembly comprising a valve body having an inlet for receiving exhaust gases from said first portion of said recirculation passage, an outlet for discharging exhaust gases to said second portion of said recirculation passage, a valve seat formed between said inlet and said outlet, and an orifice formed in said inlet and defining a control pressure zone between said orifice and said valve seat, a valve pintle associated with said valve seat for controlling flow of exhaust gases therethrough, and control means for positioning said valve pintle to maintain a substantially constant pressure in said control pressure zone, said control means including spring means biasing said valve pintle toward engagement with said valve seat, a pressure responsive member connected to said valve pintle, means defining a vacuum orifice through which said member may be subjected to the pressure in said induction passage downstream of said throttle, means defining an air bleed orifice through which said member is subjected to atmospheric air, a bleed valve associated with said bleed orifice for controlling admission of air therethrough to vary the controlled pressure created by induction passage vacuum received through said vacuum orifice and atmospheric air received through said air bleed orifice, pressure responsive means connected to said bleed valve and subjected to the pressure in said zone whereby upon an increase in pressure in said zone said pressure responsive means displaces said bleed valve to decrease admission of air through said bleed orifice and thereby decreases said controlled pressure to thereby cause said pressure responsive member to overcome the bias of said spring means and displace said valve means from said valve seat means and increase recirculation of exhaust gases, and second spring means biasing said bleed valve to permit increased admission of air through said bleed orifice whereby upon a decrease in pressure in said zone said second spring means displaces said bleed valve to increase admission of air through said bleed orifice and thereby increases said controlled pressure to thereby permit said first spring means to displace said valve means toward said valve seat means and decrease recirculation of exhaust gases, said bleed valve having a base portion and a tip portion, and which further comprises an orifice member surrounding said air bleed orifice, said orifice member having a resilient lip receiving

said tip portion of said bleed valve, and a seating rim receiving said base portion of said bleed valve after said tip portion has engaged said resilient lip.

3. An exhaust gas recirculation control valve assembly for use on an internal combustion engine having an induction passage for air flow to the engine, a throttle disposed in said induction passage for controlling air flow therethrough, an exhaust passage for exhaust gas flow from the engine, and an exhaust gas recirculation passage having a first portion extending from said exhaust passage and a second portion extending to said induction passage downstream of said throttle, said control valve assembly comprising a valve body having an inlet for receiving exhaust gases from said first portion of said recirculation passage, an outlet for discharging exhaust gases to said second portion of said recirculation passage, a valve seat formed between said inlet and said outlet, and an orifice formed in said inlet and defining a control pressure zone between said orifice and said valve seat, a valve pintle associated with said valve seat for controlling flow of exhaust gases therethrough, and control means for positioning said valve pintle to maintain a substantially constant pressure in said control pressure zone, said control means including spring means biasing said valve pintle toward engagement with said valve seat, a hollow valve stem connected to said valve pintle and extending outwardly of said valve body, a pressure responsive assembly having a first diaphragm backing member secured to said valve stem, a diaphragm having a flexible inner portion defining a control pressure chamber with said backing member, said diaphragm further having a flexible annular outer portion extending radially outwardly from said backing member, and a second diaphragm backing member defining an atmospheric pressure chamber with said inner portion of said diaphragm, a cover member defining a vacuum chamber with said outer portion of said diaphragm and said second backing member, said cover member having means for connecting said vacuum chamber to said induction passage downstream of said throttle, said inner portion of said diaphragm and said backing members having openings for admitting air to said atmospheric pressure chamber, said second backing member having an air bleed orifice for admitting air from said atmospheric pressure chamber to said vacuum chamber, a bleed valve connected to said inner portion of said diaphragm and associated with said air bleed orifice for controlling admission of air to said vacuum chamber, said hollow stem defining a passage connecting said exhaust pressure chamber to said zone, whereby upon an increase in pressure in said zone said inner portion of said diaphragm displaces said bleed valve to decrease admission of air to said vacuum chamber through said bleed orifice and thereby decreases the pressure in said vacuum chamber to thereby cause said pressure responsive member to overcome the bias of said spring means and displace said valve pintle from said valve seat and increase recirculation of exhaust gases, and second spring means biasing said bleed valve to permit increased admission of air to said vacuum chamber through said bleed orifice whereby upon a decrease in pressure in said zone said second spring means displaces said bleed valve to increase admission of air to said vacuum chamber through said bleed orifice and thereby increases the pressure in said vacuum chamber to thereby permit said first spring means to displace said valve pintle to-

ward said valve seat and decrease recirculation of exhaust gases, said bleed valve having a base portion and a tip portion, and which further comprises an orifice member surrounding said air bleed orifice, said orifice member having a resilient lip receiving said tip portion of said bleed valve, and a seating rim receiving said base portion of said bleed valve after said tip portion has engaged said resilient lip.

4. An exhaust gas recirculation control valve assembly for use on an internal combustion engine having an induction passage for air flow to the engine, a throttle disposed in said induction passage for controlling air flow therethrough, an exhaust passage for exhaust gas flow from the engine, and an exhaust gas recirculation passage having a first portion extending from said exhaust passage and a second portion extending to said induction passage downstream of said throttle, said control valve assembly comprising a valve body having an inlet for receiving exhaust gases from said first portion of said recirculation passage, an outlet for discharging exhaust gases to said second portion of said recirculation passage, a valve seat formed between said inlet and said outlet, and an orifice formed in said inlet and defining a control pressure zone between said orifice and said valve seat, a valve pintle associated with said valve seat for controlling flow of exhaust gases therethrough, and control means for positioning said valve pintle to maintain a substantially constant pressure in said control pressure zone, said control means including spring means biasing said valve pintle toward engagement with said valve seat, a hollow valve stem connected to said valve pintle and extending outwardly of said valve body, a pressure responsive assembly having a first diaphragm backing member secured to said valve stem, a diaphragm having a flexible inner portion defining a control pressure chamber with said backing member, said diaphragm further having a flexible annular outer portion extending radially outwardly from said backing member, and a second diaphragm backing member defining an atmospheric pressure chamber with said inner portion of said diaphragm, a cover member defining a vacuum chamber with said outer portion of said diaphragm and said second backing member, said cover member having means for connecting said vacuum chamber to said induction passage downstream of said throttle, said inner portion of said diaphragm and said backing members having openings for admitting air to said atmospheric pressure chamber, said second backing member having an air bleed orifice for admitting air from said atmospheric pressure chamber to said vacuum chamber, a bleed valve connected to said inner portion of said diaphragm and associated with said air bleed orifice for controlling admission of air to said vacuum chamber, said hollow stem defining a passage connecting said exhaust pressure chamber to said zone, whereby upon an increase in pressure in said zone said inner portion of said diaphragm displaces said bleed valve to decrease admission of air to said vacuum chamber through said bleed orifice and thereby decreases the pressure in said vacuum chamber to thereby cause said pressure responsive member to overcome the bias of said spring means and displace said valve pintle from said valve seat and increase recirculation of exhaust gases, and second spring means biasing said bleed valve to permit increased admission of air to said vacuum chamber through said bleed orifice whereby upon a decrease in pressure in said zone said

second spring means displaces said bleed valve to increase admission of air to said vacuum chamber through said bleed orifice and thereby increases the pressure in said vacuum chamber to thereby permit said first spring means to displace said valve pintle toward said valve seat and decrease recirculation of exhaust gases, wherein said first diaphragm backing member has a downwardly concave annular channel to which said openings extend and at least one of said diaphragm backing members has a plurality of recesses opening from said channel, and which further comprises an upwardly concave annular paper filter element disposed in said channel for preventing entrance of dirt through said openings to said atmospheric pressure chamber, and clip means secured to said filter element and received in said recesses for retaining said filter element in said channel.

5. An exhaust gas recirculation control valve assembly for use on an internal combustion engine having an induction passage for air flow to the engine, a throttle disposed in said induction passage for controlling air flow therethrough, an exhaust passage for exhaust gas flow from the engine, and an exhaust gas recirculation passage having a first portion extending from said exhaust passage and a second portion extending to said induction passage downstream of said throttle, said control valve assembly comprising a valve body having an inlet for receiving exhaust gases from said first portion of said recirculation passage, an outlet for discharging exhaust gases to said second portion of said recirculation passage, a valve seat formed between said inlet and said outlet, and an orifice formed in said inlet and defining a control pressure zone between said orifice and said valve seat, a valve pintle associated with said valve seat for controlling flow of exhaust gases therethrough, and control means for positioning said valve pintle to maintain a substantially constant pressure in said control pressure zone, said control means including spring means biasing said valve pintle toward engagement with said valve seat, a hollow valve stem connected to said valve pintle and extending outwardly of said valve body, a pressure responsive assembly having a first diaphragm backing member secured to said valve stem, a diaphragm having a flexible inner portion defining a control pressure chamber with said backing member, said diaphragm further having a flexible annular outer portion extending radially outwardly from said backing member, and a second diaphragm backing member defining an atmospheric pressure chamber with said inner portion of said diaphragm, a cover member defining a vacuum chamber with said outer portion of said diaphragm and said second backing

member, said cover member having means for connecting said vacuum chamber to said induction passage downstream of said throttle, said inner portion of said diaphragm and said backing members having openings for admitting air to said atmospheric pressure chamber, said second backing member having an air bleed orifice for admitting air from said atmospheric pressure chamber to said vacuum chamber, a bleed valve connected to said inner portion of said diaphragm and associated with said air bleed orifice for controlling admission of air to said vacuum chamber, said hollow stem defining a passage connecting said exhaust pressure chamber to said zone, whereby upon an increase in pressure in said zone said inner portion of said diaphragm displaces said bleed valve to decrease admission of air to said vacuum chamber through said bleed orifice and thereby decreases the pressure in said vacuum chamber to thereby cause said pressure responsive member to overcome the bias of said spring means and displace said valve pintle from said valve seat and increase recirculation of exhaust gases, and second spring means biasing said bleed valve to permit increased admission of air to said vacuum chamber through said bleed orifice whereby upon a decrease in pressure in said zone said second spring means displaces said bleed valve to increase admission of air to said vacuum chamber through said bleed orifice and thereby increases the pressure in said vacuum chamber to thereby permit said first spring means to displace said valve pintle toward said valve seat and decrease recirculation of exhaust gases, said bleed valve having a planar base portion and a tapered tip portion, an orifice member surrounding said air bleed orifice, said orifice member having a resilient lip receiving said tip portion of said bleed valve, and a planar seating rim receiving said base portion of said bleed valve after said tip portion has engaged said resilient lip, wherein said first diaphragm backing member has a downwardly concave annular channel to which said openings extend and at least one of said diaphragm backing members has a plurality of recesses opening from said channel, an upwardly concave annular paper filter element disposed in said channel for preventing entrance of dirt through said openings to said atmospheric pressure chamber, clip means extending through said filter element and received in said recesses for securing said filter element in said channel, and rivet means extending between said second backing member and said channel portion of said first backing member and extending through said diaphragm to securely interconnect said diaphragm and said backing members.

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