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(54) An exhaust gas recirculation system.

(57) The invention relates to an exhaust gas recirculation (EGR) system for controlling EGR flow in an internal combustion engine. The system comprises an EGR passage (39, 40) and an EGR valve (28) in the passage, opening and closing of the EGR valve being controlled by vacuum provided from the engine manifold (30). A vacuum regulator (29) regulates engine manifold vacuum and passes a regulated manifold vacuum to the EGR valve. A vacuum trap (1) is arranged between the vacuum regulator (29) and the EGR valve (28) to trap in the EGR valve a predetermined level of vacuum, the vacuum trap comprising a valve (12, 13) adapted to close when the level of manifold vacuum drops below a predetermined level, and a bleed passage (24, 26) which allows the trapped vacuum to decay.

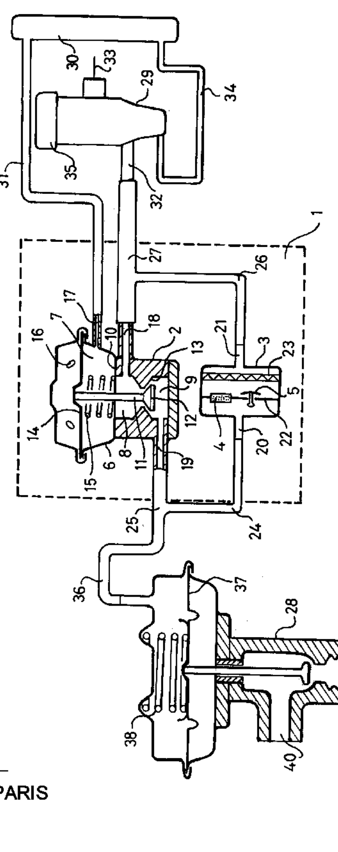

Fig. 1

EP 0 666 413 A1

This invention relates to an exhaust gas recirculation system, especially for a motor vehicle, and to a vacuum trap arrangement for use in such a system.

The addition of an exhaust gas recirculation system (often referred to as an EGR system) to the exhaust system of an internal combustion engine, particularly an engine of a motor vehicle, has been adopted by the motor industry with a view to reducing the level of oxides of nitrogen emitted by motor vehicles into the atmosphere.

The basic function of an EGR system is aimed at returning to the inlet manifold of an internal combustion engine, at least a proportion of, the exhaust gases produced by the engine. This serves to reduce peak engine combustion temperatures, hence inhibiting the formation of oxides of nitrogen.

In order to manage the control of the exhaust gases, an EGR system generally includes an EGR valve, the operation of which may be controlled by reduced pressure communicated directly or indirectly from the inlet manifold of the associated internal combustion engine.

In one known EGR system, the EGR valve is controlled by the application of a modulated vacuum signal produced by an electronic vacuum regulator (often abbreviated to EVR) connected between the EGR valve and the induction manifold or ports of the engine. The EVR is connected to an electronic control module from which it, in turn, receives a control signal dependent on inputs of engine parameters such as speed, load, temperature and exhaust gas pressure differential across a constriction upstream of the EGR valve. Other types of vacuum regulator connected between the EGR valve and the induction manifold of the engine may alternatively be employed to control the operation of the EGR valve.

Vacuum operated EGR valves are normally designed to open fully at a predetermined vacuum level, for example at a level equivalent to 20 kPa (6 ins. of mercury) and to close at some predetermined lower vacuum level, for example at a level below 5 kPa (1.5 ins. of mercury).

In the above-mentioned EGR systems employing a vacuum regulator, such as an EVR for example; when the vacuum level in the induction manifold falls below that necessary to fully open the EGR valve, say 20 kPa, the EGR valve may not be set fully open because the vacuum regulator is unable to provide a vacuum greater than that in the manifold. It will be appreciated that the modulated vacuum signal produced by an EVR, may be set at any value, for example between 0 and 20 kPa, provided the vacuum in the manifold is at least as high. When the vacuum in the manifold falls below the level necessary to fully open the EGR valve, the extent of operation of the EGR valve is restricted by the maximum vacuum in the manifold.

With general aims, and indeed legislation, requiring lower emissions of oxides of nitrogen into the atmosphere from motor vehicles, attention has been directed by the motor industry to extending the range of use of EGR systems. In this connection, it is known that large amounts of oxides of nitrogen are produced during hard acceleration and heavy cruise conditions of engine operation.

Accordingly, it can be advantageous to have an EGR system in operation when such conditions prevail, but the vacuum level in the intake manifold of some engines under such conditions is too low to operate the EGR valve.

Proposals have been made, such as in USA patent specification 4 563 998, to incorporate a vacuum trap device in an EGR system whereby an EGR valve may be maintained in the open condition depending on the position of a by-pass valve and optionally, as a function of time, by providing the vacuum trap with a by-pass throttle. The by-pass throttle therein proposed provides direct and constant communication between the vacuum input side of the EGR valve and the engine induction manifold, albeit via an intermediate thermostatic valve. Thus, a vacuum applied to the EGR is constantly allowed to decay to the manifold value.

According to the proposals described in USA patent specifications 4267809 and 4359034, an EGR system is provided with a positive pressure delay valve in a negative pressure passage to maintain a negative pressure in an EGR valve during acceleration. The delay valve comprises a one-way valve and an adjacent orifice for pressure equalization of connected chambers. While the orifice may be fitted with a sintered metal plug to obtain the most suitable flow resistance over a certain period, operation of the one-way valve is controlled by a change in the applied induction manifold pressure, as may be modified upwards by exhaust pressure sensors. Further, the delay valve always allows the negative pressure it initially traps, to decay to the induction manifold pressure, as may be modified as above-mentioned, subsequently applied to it.

According to the present invention there is provided an exhaust gas recirculation system for controlling EGR flow in an internal combustion engine, the system comprising an EGR passage and an EGR valve in the passage, opening and closing of the EGR valve being controlled by vacuum provided from the engine manifold, wherein a vacuum regulator is provided to regulate engine manifold vacuum and to pass a regulated manifold vacuum to the EGR valve, and wherein a vacuum trap is provided between the vacuum regulator and the EGR valve for trapping in the EGR valve a predetermined level of vacuum; the vacuum trap comprising a valve adapted to close when the level of manifold vacuum drops below a predetermined level, and a bleed passage which allows the trapped vacuum to decay.

As a result it is possible to construct an EGR system in which:

a) the range of EGR valve operation is extended such that it can remain open if the vacuum level in the induction manifold or induction port of the engine falls below the maximum EGR valve operating level.

b) the extension of the range of EGR valve operation may apply only apply for a predetermined range of induction manifold or port vacuum levels e.g. at values below 20 kPa, and outside that predetermined range the vacuum trap arrangement may be at least substantially transparent to the EGR system operation.

c) the EGR valve is allowed to close if the applied regulated pressure is 0 kPa or to adjust according to an applied regulated negative pressure supplied by the negative pressure regulator.

d) the first valve, in operating in response to vacuum levels in the induction manifold or port permits its rapid closure, important to the efficient trapping of a regulated negative pressure for application to the EGR valve.

The invention also provides a vacuum trap for use in the EGR system as claimed in any preceding claim, having a vacuum operated valve which can open to allow passage of vacuum and can close to trap vacuum on one side and a bypass passage with a vacuum decay device which allows any trapped vacuum to decay.

The vacuum trap valve preferably comprises a unitary assembly of component parts. Such a unitary assembly preferably comprises a housing divided into three chambers. The first chamber preferably has a transverse diaphragm to which is attached a controlling end of a stem of the first valve, which stem preferably extends between at least two of the three chambers. Preferably the stem terminates in, or has at least near its other end, a valve head adapted to cooperate with a valve seat or face positioned on the boundary between the second and third chambers. The first chamber is preferably substantially isolated from the second and third chambers. The diaphragm of the first chamber is preferably supported against deflection by a spring, preferably a compression spring, of calibrated strength. First, second and third ducts are preferably connected to the housing in communication respectively with the first second and third chambers. The diaphragm and first duct are preferably positioned such that application of a negative pressure of sufficient level to overcome the resistive forces of the diaphragm, and spring if employed, to the first chamber causes deflection of the diaphragm with consequential opening of the first valve.

The first valve, is preferably calibrated such that it will close when applied negative pressures fall to below 20 kPa.

The vacuum decay device may be a suitably dimensioned orifice or a sintered metal disc for example, and may be positioned, for example, in a by-pass duct connecting the second and third ducts thereby by-passing the vacuum trap valve. Alternatively, the vacuum decay device may be positioned, for example in the wall of the third chamber with its outer side in communication with atmospheric pressure.

It is preferred that a filter is associated with the decay device and positioned on the higher pressure side of the device.

The second valve may be positioned, for example, in a by pass duct connecting the second and third ducts in which case it is preferably positioned adjacent a decay device positioned therein whereby the decay device is by-passed in the event of the second valve being subjected to reverse pressure from the EGR valve, for example, via the third duct. Alternatively, for example, the second valve may be incorporated in the first valve in which case the head of the first valve preferably comprises a flexible diaphragm which may be distorted by the above-mentioned reverse pressure despite the first valve being ostensibly, and therefore otherwise, in its closed position.

The EGR valve may be of conventional type such as that more particularly described with reference to the accompanying drawings.

The EGR valve is preferably calibrated such that it begins to open on application of a negative pressure of about 5 kPa and is fully opened by the application of 20 kPa.

The negative pressure regulator is preferably an electronic vacuum regulator connected by vacuum ducting on its input side to a position in the induction manifold or port and electrically connected for receiving control signals from an electronic control module. Such an electronic control module may receive input signals from a multiplicity of engine parameter sensors such as sensors of the speed of revolutions, load, temperature and pressure difference across a control venturi constriction in the exhaust feed connection to the EGR valve, for example.

It is preferred that the negative pressure regulator is calibrated to provide a regulated negative pressure within the range of 0 to 20 kPa induction manifold or port input values of up to 20 kPa negative pressure but such as to provide a fully variable negative pressure for induction manifold or port input values higher than 20 kPa negative pressure.

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a diagram showing an exhaust gas recirculation system according to the invention;

Figure 2 is a cross-section through a vacuum trap arrangement of a second embodiment of the invention;

Figure 3 is a cross-section through a vacuum regulator and vacuum trap of a third embodiment of the invention; and

Figure 4 is a cross-section through a vacuum trap of a fourth embodiment of the invention.

Figure 1 shows a vacuum trap arrangement indicated generally by 1, which comprises a vacuum trap valve 2 and an enclosure 3 containing a vacuum decay device in the form of a sintered metal disc 4 and a one-way umbrella valve 5. The vacuum trap valve 2 comprises a unitary housing 6 which is divided into three chambers 7,8 and 9. Chambers 7 and 8 are substantially isolated from one another and their separating wall 10 is traversed only by the stem of the first valve 11 which has a head 12 adapted to cooperate with the valve seat 13 when the first valve 11 is in the closed position and whereby communication between the chambers B and 9 internally of the vacuum trap valve 2 may be shut off. The chamber 7 has a transversely arranged diaphragm 14 to the centre of which is fixed the tail end of the stem of the first valve 11. The diaphragm 14 is supported by a helical compression spring 15 which is calibrated such that when the negative pressure within the chamber 7 falls to below 20 kPa the diaphragm causes the first valve 11 to close with the valve head 12 cooperating in sealing manner with the valve seat 13. The side of the diaphragm opposite to the chamber 7 is open to the free atmosphere via apertures 16. Communicating with the chambers 7, 8 and 9 respectively are first, second and third ducts 17, 18 and 19 connected to the housing 6 appropriately.

The enclosure 3 has tubular connections 20 and 21 communicating respectively with each side of a partitioning plate 22 in which the sintered disc 4 and the umbrella valve 5 are mounted. In addition, the enclosure 3 houses a filter 23 arranged parallel to the partitioning plate 22. The tubular connection 20 is attached to the duct 19 by a conduit 24 and a T-connector 25. The tubular connection 21 is attached to duct 18 by a conduit 26 and a T-connector 27.

The vacuum trap arrangement 1 is connected into the EGR system illustrated in Figure 1, which also comprises an EGR valve 28, a negative pressure regulator 29 and an induction manifold 30 of an internal combustion engine of a motor vehicle.

The duct 17 is connected to the induction manifold 30 by conduit 31. The duct 18 is connected to the negative pressure regulator 29 by the T-connector 27 and a regulator output tube 32. The negative pressure regulator 29 can be an electronic vacuum regulator (EVR) of known type, such as a regulator supplied by Siemens Automotive Limited under the designation F0TE-9J459-AIA, having a control signal input, from an electronic control module on the motor vehicle, being fed in at conductor 33. The EVR is connected to the induction manifold 30 by a conduit 34 and has a vent 35 giving access to atmospheric pressure. The EVR is calibrated such that the regulated negative pressure output is in the range 0 to 20 kPa for an input vacuum of up to 20 kPa and the output is fully variable if the input vacuum is greater than 20 kPa.

The negative pressure regulator 29 receives input signals from engine sensors comprising sensors monitoring, for example, engine speed, engine load, temperature and pressure difference across a control venturi constriction (not shown) in an exhaust pipe attached to an exhaust manifold connector 39.

The duct 19 is connected to the EGR valve 28 by a conduit 36 and the T-connector 25.

The EGR valve can be of a known type, such as a valve supplied by Borg Warner Automotive Controls Inc under the designation 93BB-9D477-AC, and has a vacuum operated diaphragm 37 supported by a helical spring 38 calibrated such that the EGR valve will begin to open at an applied negative pressure of 5 kPa and will be opened fully by an applied negative pressure of 20 kPa. When the EGR valve is open, communication is established between the exhaust manifold connector 39 and an induction manifold connector 40.

The vacuum trap arrangement 1 and the EGR system in which it is incorporated operate as follows:

With the engine, to which the system is attached, running at its normal working temperature, a negative pressure is created in the induction manifold 30 and such negative pressure is transmitted to the chamber 7 by conduit 31, and to the EVR 29 by conduit 34. The input signal fed into the EVR 29 at the conductor 33 from the electronic control module (not shown) causes the EVR 29 to modulate the induction manifold pressure and to output a modulated pressure at output tube 32 corresponding to the correct positioning of the EGR valve 28 under stable operation of the engine. When the induction manifold negative pressure is high, that is, between 20 and 100 kPa, such as when the manifold throttle valve is closed on deceleration, the vacuum trap valve 2 will be opened by the effect-of that pressure in the chamber 7 drawing down the diaphragm 14 against the action of the spring 15. Thus, communication is established between the output tube 32 and the conduit 36 via the valve 2 whereby a modulated negative pressure of 20kPa, is applied to the EGR valve 28. If the engine is then subjected to a heavy load with the induction manifold throttle valve being opened widely, the negative pressure in the induction manifold 30 drops. As soon as the negative pressure in the manifold 30 falls to below 20 kPa, the vacuum trap valve 2 is caused to close by the spring 15, thus trapping the EVR modulated pressure in the chamber 9 whereby the EGR valve 28 may be held fully open. If a low vacuum continues to prevail in the induction manifold 30, the EGR valve 28 is prevented from remaining open by the sintered disc 4 allowing the controlled decay of the trapped negative pressure down to the new EVR output level. It will be appreciated that the EVR is not able to have a negative output pressure which is above the input value from the induction manifold. If the engine speed has risen above 4000 RPM, then eventually the EGR valve closes allowing full power to be reached.

Before the engine speed has risen to be above 4000 RPM, the EVR 29 will still be trying to set a modulated negative pressure accordingly, so that the decay of the trapped negative pressure, via the sintered disc 4 and the filter 23, will only occur down to the EVR output level. If the EVR output level then increases within the range 0 to 20 kPa, the pressure applied to the EGR valve is quickly and automatically adjusted by means of the one way umbrella valve 5.

With reference to Figure 2; the vacuum trap arrangement indicated generally by 101, comprises a vacuum trap valve 102 having a unitary housing 103 which also contains a vacuum decay device in the form of a sintered metal disc 104. A second valve is formed by a flexible structure of the valve head 105 of a first valve 106. The unitary housing 103 is divided into three chambers 107, 108 and 109. The chambers 107 and 108 are substantially isolated from one another by a separating plate 110 and a flexible diaphragm 111 supported on a spring cup 112. The separating plate 110 is traversed only by the stem of the first valve 106 which has a valve head 105 which is of flexible structure enabling it readily to make sealing engagement with a face 113 of the chamber 108 when the first valve is in its closed position and whereby, subject to absence of the operation of the second valve feature of the valve head 105, communication between the chambers 108 and 109 internally of the vacuum trap valve 102 may be shut off. The spring cup 112 has a base centrally profiled such as to accommodate the tail end of the stem of the first valve 106 and to which it is firmly fixed. The spring cup 112 accommodates the helical spring 114 which is calibrated such that when the negative pressure within the chamber 107 falls to below 20 kPa, the diaphragm 111 and the cup 112 causes the first valve to close with the valve head 105 cooperating in sealing manner with the face 113 subject to the absence of operation of the second valve feature incorporated in the valve head 105. The side of the diaphragm 111 opposite to the chamber 107 is open to the free atmosphere via apertures (not shown) in the wall of the housing 103. The stops 115 on the diaphragm 111 space the main body of the diaphragm from the plate 110 when the valve 106 is in its closed position.

Communicating with the chambers 107, 108 and 109 respectively are first, second and third ducts 116, 117 and 118 connected to the housing 103 appropriately. In the wall separating the chambers 108 and 109 and bearing the face 113, apertures 119 are provided. In the opposite wall of the chamber 109 a recessed aperture 120 is provided to accommodate the sintered disc 104 with one side in constant communication with the chamber 109 and the other in communication with atmospheric pressure via the filter 121 and the housing aperture 122.

The vacuum trap arrangement 101 when incorporated in the EGR system shown in Figure 1 in place of the vacuum trap arrangement 1 provides an EGR system which operates in a manner very similar to that described with reference to Figure 1. However, there are differences which warrant a specific description as follows:

With the engine to which the system is attached, running at its normal working temperature, the negative pressure created in the manifold 30 is transmitted to the chamber 107 by the conduit 116, and to the EVR 29 by the conduit 34. The input signal fed into the EVR 29 at the conductor 33 from the electronic control module (not shown) causes the EVR 29 to modulate the induction manifold pressure and to have an output pressure at output tube 32 as described with reference to the EGR system of Figure 1. The output tube 32 is connected to the duct 117 of the vacuum trap arrangement of Figure 2. The duct 118 is connected to the EGR valve by a conduit in place of the conduit 36 of Figure 1. When the induction manifold negative pressure is high, that is, between 20 and 100 kPa, the first valve 106 will be opened by the effect of that pressure in the chamber 107 drawing down the diaphragm 111 against the action of the spring 114. Thus, communication is established between the output tube 32 and the EGR valve 28 via the valve 106 whereby the modulated negative pressure of 20 kPa is applied to the EGR valve 2)3. If the engine is then subjected to a heavy load with the induction manifold throttle valve being opened widely, the negative pressure in the manifold 30 drops. Due to the calibration of the spring 114, as soon as the negative pressure in the manifold 30 falls to below 20 kPa, the valve 106 is caused to close with the flexible valve head 105 making sealing contact with the face 113. Thus, the EVR modulated negative pressure is trapped in the chamber 109 whereby the EGR valve 28 may be held fully open. If the engine speed then increases to above 4000 RPM while a low vacuum still prevails in the induction manifold 30, the EGR valve 28 is prevented from remaining open in a region of the calibration not normally requiring exhaust gas recirculation, by the sintered disc 104 in the recessed aperture 120 allowing the controlled decay of the trapped negative pressure down to atmospheric pressure via the filter 121 and the housing aperture 122. If the engine speed has risen above 4000RPM, then eventually the EGR valve closes allowing full engine power to be reached.

Before the engine speed has risen above 4000 RPM, the EVR 29 will still be trying to set a modulated negative pressure. If the negative pressure in the chamber 108 rises above that in the chamber 109, the pressure difference between the chambers 108 and 109 causes the second valve incorporated as a feature of the valve head 105, to come into operation whereby the flexibility of the valve head 105, particularly the peripheral edges, and lift, allowing the pressures in the two chambers to equilibrate whereby the pressure applied to the EGR valve 28 is automatically adjusted accordingly.

It will be appreciated that the vacuum trap valve of this invention is such that movement of the first valve to its closing position, subject to the absence of operation of any second valve feature incorporated therein, is independent of the level of the modulated negative pressure output of the negative pressure regulator.

The embodiment of Figure 3 will now be described, making use of the same reference numerals for the same parts as previously used in connection with Figure 1.

In this embodiment, the vacuum trap arrangement is connected directly to the vacuum (negative pressure) regulator 29, and the unmodified manifold vacuum is fed first through the chamber 7 of the vacuum trap arrangement and then to the inlet port 34 of the vacuum regulator. In this respect, the vacuum trap arrangement and the vacuum regulator of Figure 3 are in series with respect to the manifold vacuum signal, rather than being in parallel as shown in Figure 1.

The vacuum regulator has an input port 33a for receiving an electronic control system from an engine management module. This signal controls the electro-magnetic windings 50 of a solenoid which has a movable armature 52. The vertical position of the bottom face 54 of the armature will therefore be controlled by the control signal entering through the port 33a.

At the bottom of the vacuum regulator is a freely floating seal plate 56. This plate floats under the influence on one side of vacuum in the passage 34 and on the other side of ?? to modulate the vacuum output from the regulator through the passage 18.

It must be remembered that "output of vacuum" corresponds to "intake of air" through the passage.

As the manifold vacuum passes through the chamber 7 on its way to the vacuum regulator, the vacuum will normally be sufficient to pull down on the diaphragm 14, overcoming the force of the spring 15, to pull the stem 11 and the valve head 12 off the valve seat to open communication between the passage 18 and the passage 19. In this condition, modified manifold vacuum is fed to the EGR valve.

However, if the manifold vacuum drops below a preset limit, the force of the spring 15 will overcome the force of the vacuum, and the manifold 14 will rise again to the position shown in Figure 3 such that the valve head 12 closes the valve and shuts off communication between the vacuum regulator and the EGR valve. The vacuum is then trapped in the EGR valve and in passage 19, but this vacuum will dissipate over a period of time (for example 60 seconds) by leaking through the sintered disk 4.

If the vacuum in the passage 18 rises to a level above that in the chamber 9, then equilibrium will quickly be established by opening of the umbrella valve 5.

Figure 4 shows on a larger scale part of the vacuum trap arrangement 1, with an additional feature incorporated. In this figure, the connections to and from the vacuum regulator (18, 34) cannot be seen because they are located at 90° to the plane of the paper.

The construction of this component is broadly similar to that already described with reference to Figure 3, but it is to be noted that the valve stem 11 has a central passage 16; at the bottom of the stem 11 is a shoulder 62 which carries a seal ring 64. A compression spring 66 normally forces this seal ring 64 into sealing contact with a lip 68.

Under most conditions, the spring 66 keeps the gap between the shoulder 62 and the lip 68 sealed and then the unit works as previously described.

However if this gap is open, by compression of the spring 66, then vacuum in the chamber 9 will escape through the bore 60, around the shoulder 62 and to atmosphere via the chamber 70 which is connected to atmosphere through a vent (not shown in this figure but corresponding to vents 16 in Figures 1 and 3). In other words, air from the atmosphere will rush in through the path just described to negate the vacuum in the chamber 9 and in the EGR valve.

The gap is actually opened when the manifold vacuum in the chamber 7 drops to a very low level, for example below 5 kPa. When this happens, the spring 15 lifts the diaphragm support 72 so far that the stem 11, which cannot move any further axially because of the closure of the valve at 12, cannot follow the last upward (in the orientation shown in Figure 4) movement of the carrier 72, and a gap opens between the lip 68 and the shoulder 62. This situation will occur at wide open throttle which is the situation where manifold vacuum is at its lowest level. It allows the trapped vacuum from the chamber 9 to be dumped very quickly when full engine power is required at short notice.

Claims

1. An exhaust gas recirculation (EGR) system for controlling EGR flow in an internal combustion engine, the system comprising an EGR passage (39, 40) and an EGR valve (28) in the passage, opening and closing of the EGR valve being controlled by vacuum provided from the engine manifold (30), wherein a vacuum regulator (29) is provided to regulate engine manifold vacuum and to pass a regulated manifold vacuum to the EGR valve, and wherein a vacuum trap (1) is provided between the vacuum regulator (29) and the EGR

valve (28) for trapping in the EGR valve a predetermined level of vacuum; the vacuum trap comprising a valve (12, 13) adapted to close when the level of manifold vacuum drops below a predetermined level, and a bleed passage (24, 26) which allows the trapped vacuum to decay.

2. An exhaust gas recirculation system as claimed in Claim 1, wherein the vacuum trap (1) comprises a housing (2) with first, second and third ports (17, 18, 19) wherein the vacuum trap valve is adapted for movement to an open position by the application of a predetermined vacuum at the first port (17), to establish communication between the second port (18) and the third port (19), the second port (18) being connected to the vacuum regulator (29) and the third port (19) being connected to the EGR valve (28).

3. An exhaust gas recirculation system as claimed in Claim 2, wherein the bleed passage (24, 26) extends between the second (18) and third (19) ports and includes a restricted gas passage (4) through which gas can pass at a restricted rate to allow trapped vacuum to decay.

4. An exhaust gas recirculation system as claimed in Claim 2 or Claim 3, wherein the bleed passage (24, 26) also includes a non-return valve (5) which can open to allow gas to pass from the third port (19) to the second port (18) but which prevents gas flow in the opposite direction.

5. An exhaust gas recirculation system as claimed in any preceding claim, wherein the vacuum trap valve (11, 12) is a diaphragm operated valve, with a diaphragm (14) and a spring (15) urging the valve in one direction.

6. An exhaust gas recirculation system as claimed in any preceding claim, wherein the vacuum regulator (29) is an electronic vacuum regulator.

7. An exhaust gas recirculation system as claimed in any preceding claim, wherein the vacuum regulator (29) and the vacuum trap (1) are connected directly to one another, and the manifold vacuum feed (34) to the vacuum regulator passes through a control passage (7) of the vacuum trap before reaching the regulator (29).

8. An exhaust gas recirculation system as claimed in any preceding claim, wherein the vacuum regulator (29) is adapted to provide a regulated negative pressure in the range 0 - 20 kPa.

9. An exhaust gas recirculation system as claimed in any preceding claim, wherein the EGR valve (28) is adapted to start to open at an applied vacuum of 5 kPa and to be fully open at an applied vacuum of 20 kPa.

10. A vacuum trap for use in the EGR system as claimed in any preceding claim, having a vacuum operated valve (11, 12) which can open to allow passage of vacuum and can close to trap vacuum on one side; and a bypass passage with a vacuum decay device which allows any trapped vacuum to decay.

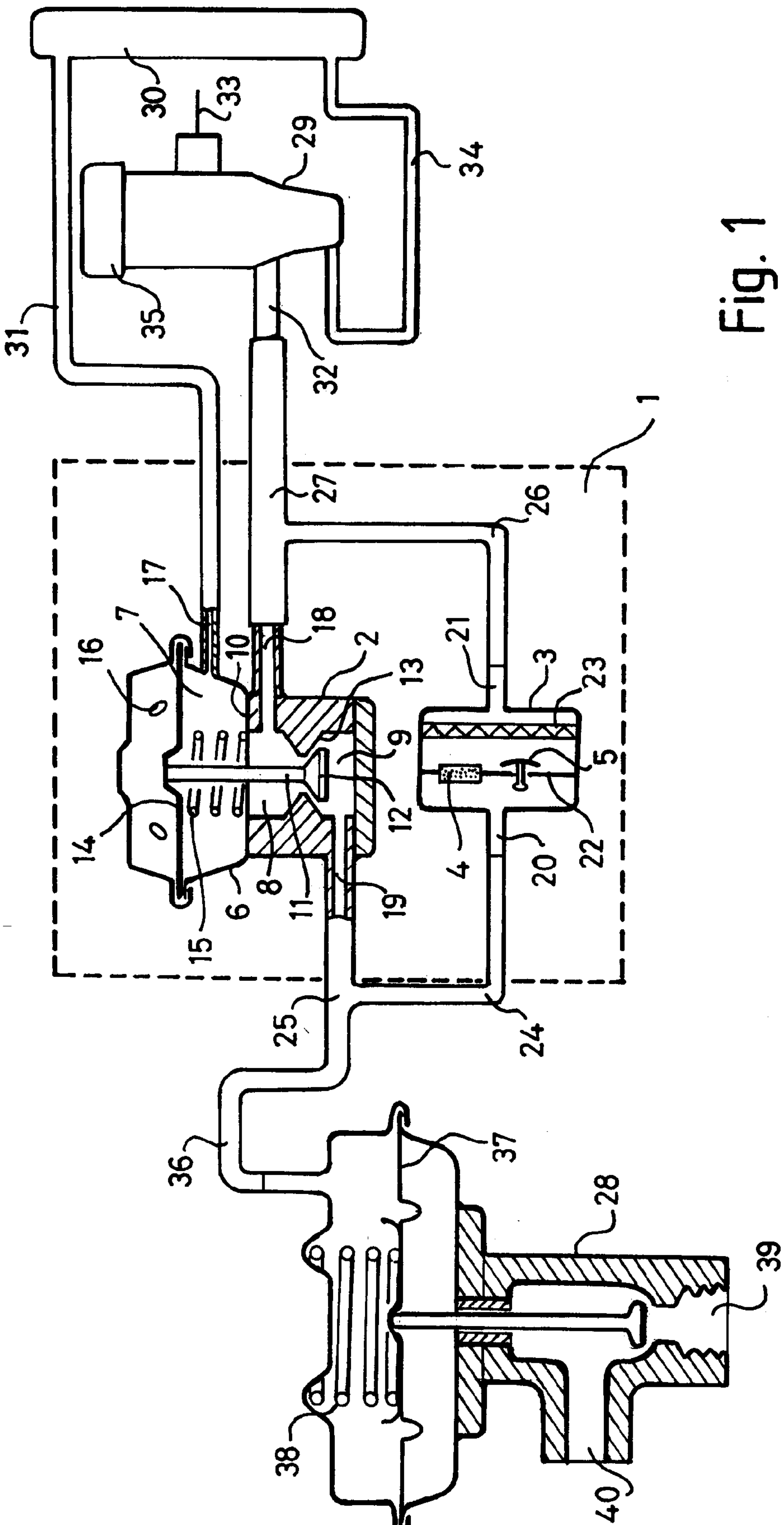
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Fig. 1

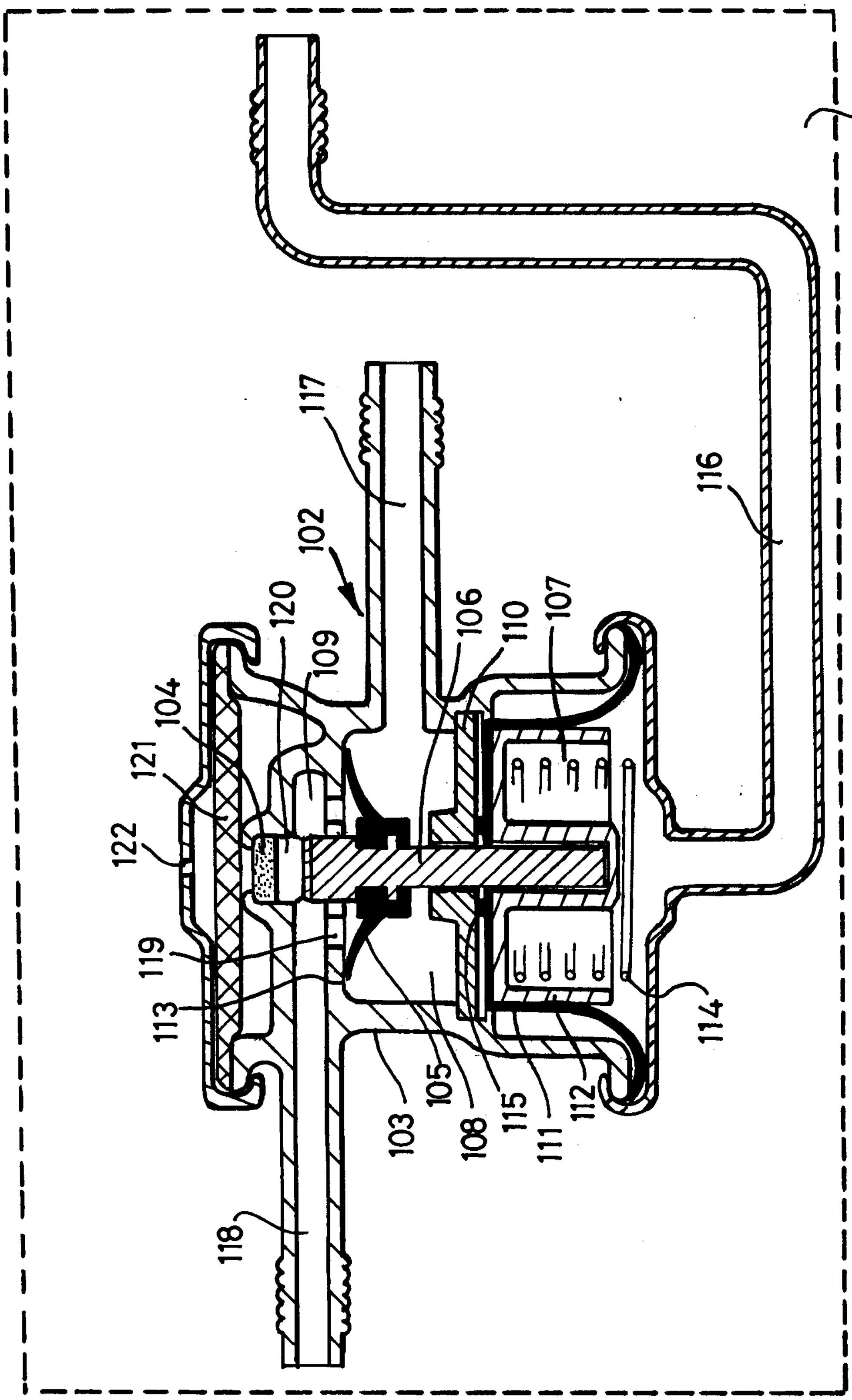
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Fig. 2

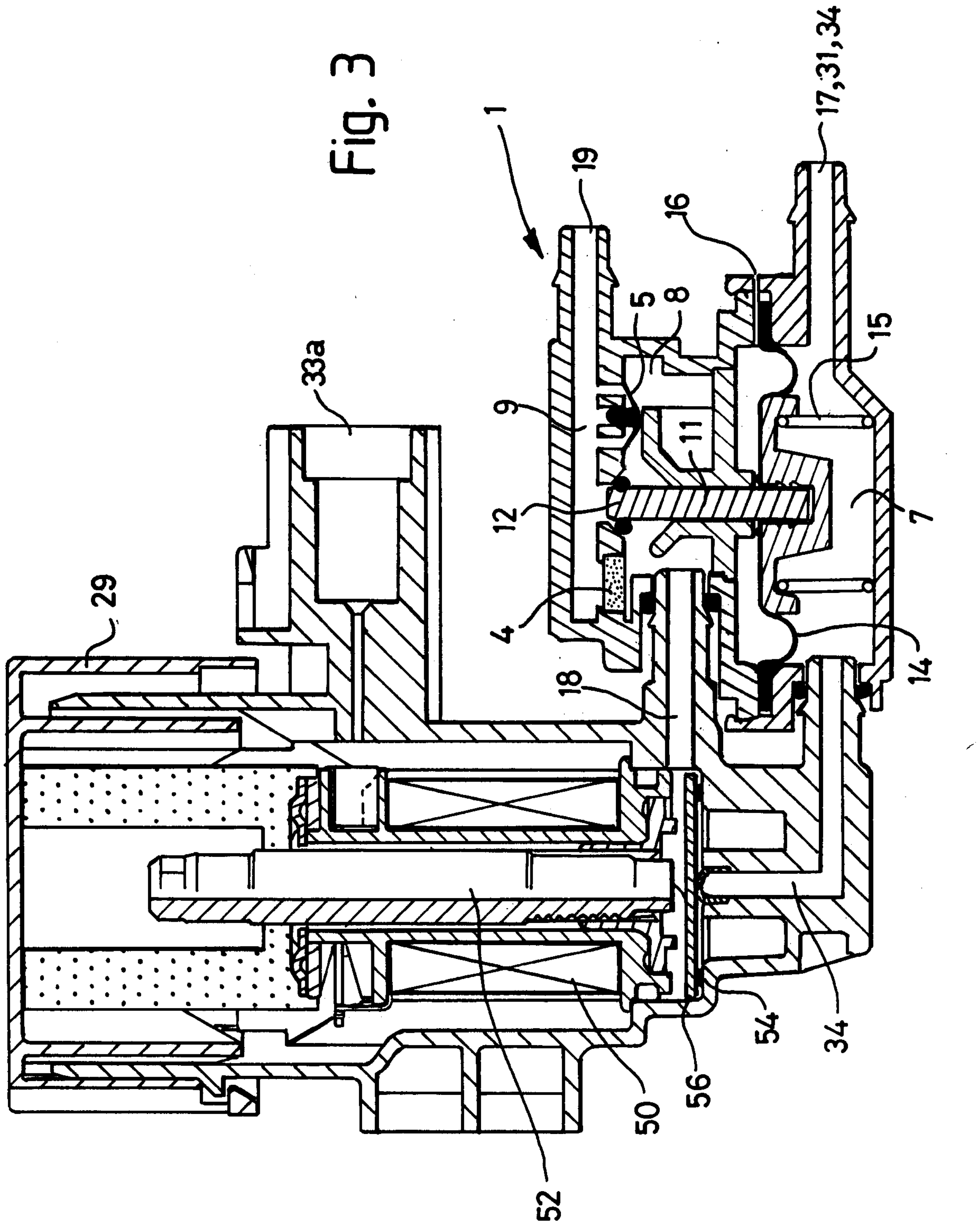

Fig. 3

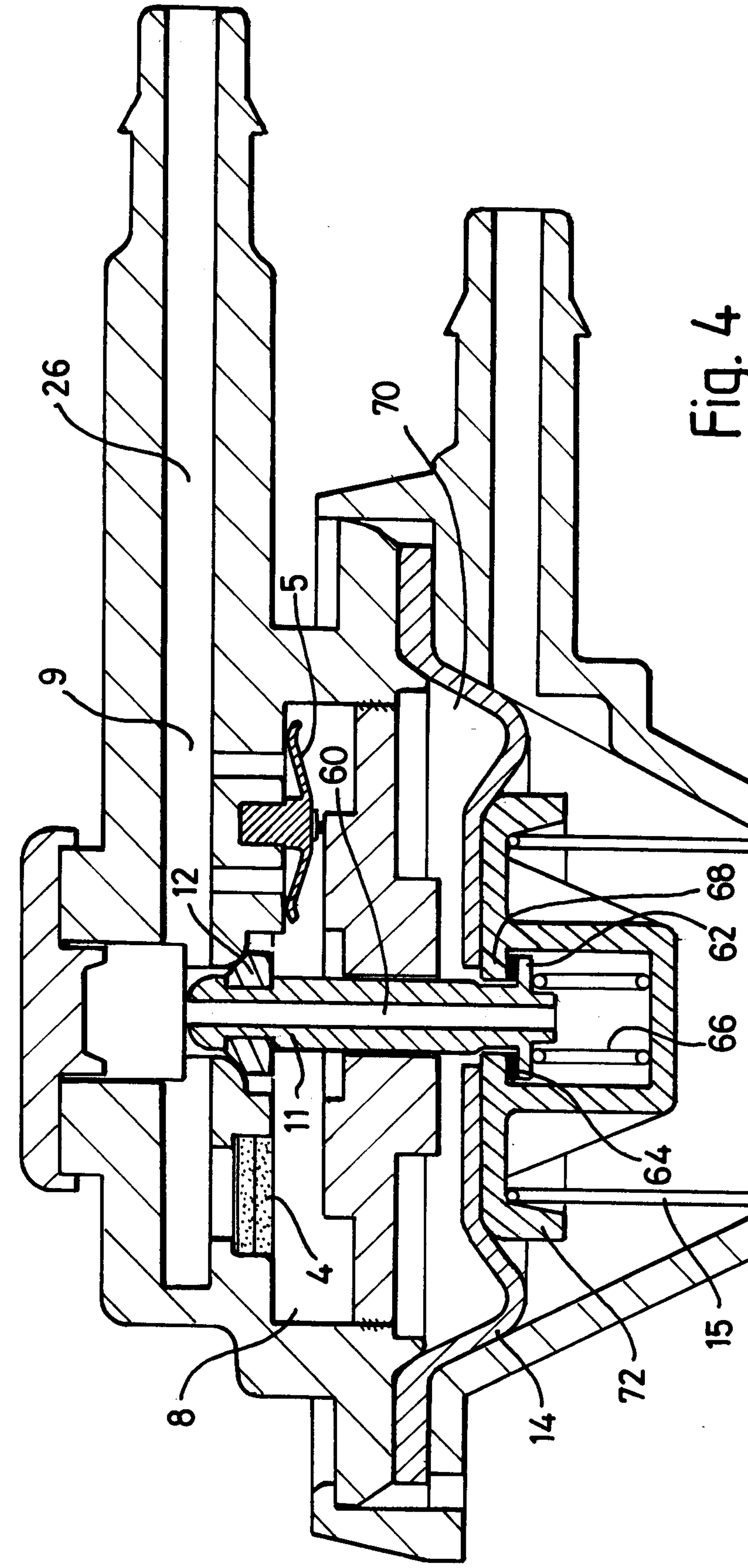

Fig. 4

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 95 30 0548

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
D,X	US-A-4 267 809 (MASE ET AL.) * column 2, line 14 - line 29 * * column 34, line 4 - column 4, line 11 *	1	F02M25/07
X	EP-A-0 184 436 (FORD MOTOR CO. LTD.) * page 3, line 16 - page 5, line 6; figures 1,3 *	1	
D,A	US-A-4 563 998 (WEINING ET AL.) * column 3, line 62 - line 65 * * column 4, line 39 - line 43 *	1	
A	US-A-3 992 878 (MOORMAN) * abstract; figures *	1	
A	EP-A-0 105 808 (CANADIAN FRAM LIMITED) * abstract; figure 1 *	1	
A	GB-A-2 076 942 (BORG-WARNER CORP.) * abstract; figure 1 *	1	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
F02M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 May 1995	Alconchel y Ungria,J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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