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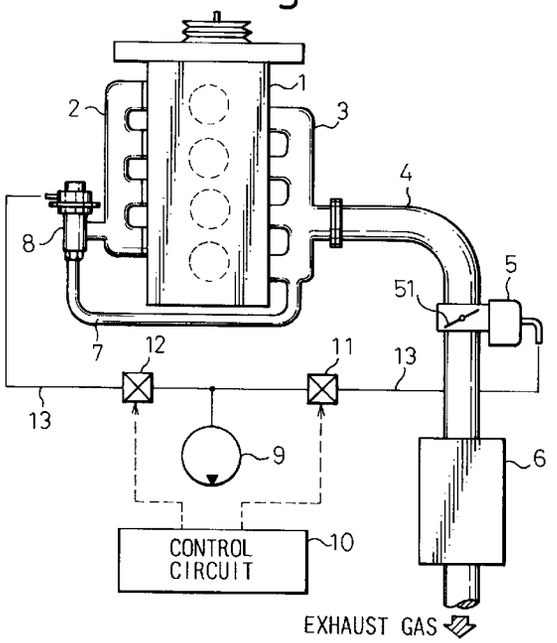
(54) EGR Device for internal combustion engine equipped with exhaust-gas brake.

(57) In an internal combustion engine having an exhaust-gas brake device (5,51) in exhaust-gas pipe (4) and an EGR device (7,8) which returns part of the exhaust-gas from the exhaust-gas pipe upstream from this exhaust-gas brake device to the air-intake manifold (2), a suitable exhaust-gas-brake force can be obtained by setting the opening pressure required to open the exhaust-gas valve (30) to a value which allows the production of a suitable exhaust-gas-braking force but lower than the opening pressure required to open the EGR control valve (8) of EGR device. As a result, when the exhaust-gas brake operates, the leakage of exhaust-gas into the air-intake manifold is eliminated, and the desired exhaust-gas-braking force is achieved.

Fig.1



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BACKGROUND OF THE INVENTION

1. Field of the invention

The present invention relates to an EGR (exhaust-gas recirculation) device for an internal combustion engine equipped with an exhaust-gas brake, and more specifically to an EGR device, for an internal combustion engine equipped with an exhaust-gas brake, which can prevent an undesirable recirculation of the exhaust-gas through the EGR device when the exhaust-gas brake is operated.

2. Description of the Related Art

In order to reduce the amount of NOx (nitrogen oxides) in the exhaust-gas, an exhaust-gas recirculation (hereafter referred to as EGR) device has been used. The EGR device recirculates exhaust-gas to an air-intake passage via a recirculation passage (hereafter referred to as an EGR passage) usually provided between an exhasut manifold and an intake manifold. In such an EGR device, an EGR control valve is usually provided within the EGR passage. This EGR control valve controls the amount of exhaust-gas supplied to the air-intake passage.

In a large vehicle, such as a truck, a bus, and such like, an exhaust-gas brake device is used as an assisting brake system. The exhaust-gas brake device has a cutoff valve disposed midway in the exhaust-gas passage. When the cutoff valve is closed, the exhaust-gas passage is blocked, thereby increasing the backpressure. The increased backpressure creates a braking action at the engine of the vehicle by means of increased pumping resistance. When a conventional exhaust-gas brake is operated, and if the backpressure increases above a certain pressure, the exhaust valves of the engine are forcibly pushed down by means of the backpressure during the intake cycle. As a result, the opening of the exhaust valves allows exhaust-gas to escape from the exaust passage, thereby preventing the backpressure exceeding the predetermined value.

In an internal combustion engine equipped with an exhaust-gas brake and an EGR device for controlling exhaust emissions of NOx, the increase in backpressure due to the operation of the exhaust-gas brake causes the EGR control valve to be forcibly pushed open. If the EGR control valve is forcibly opened, it allows exhaust-gas to escape via the EGR passage, resulting in a drop in backpressure and leading to the problem of a reduction in the exhaust-gas braking action.

To solve this problem, an EGR device, which increases the opening force on the EGR control valve when the exhaust-gas brake is operated, is proposed in the Japanese Unexamined Utility Model Publication No. 63-79463. In this EGR device, the stem of the EGR control valve is mounted on a diaphragm provided in a diaphragm chamber of the EGR device. The diaphragm chamber is divided, into an opening pressure chamber, with a spring inside thereof and a closing pressure chamber by the diaphragm. The opening pressure of the EGR control valve is set by the spring in the opening pressure chamber.

In the device proposed in the Japanese Unexamined Utility Model Publication No. 63-79463, when the exhaust-gas brake was not operated, the EGR control valve closing pressure chamber is open to atmospheric pressure. The EGR control valve is opened by applying a vacuum which exceeds the closing force of the spring provided inside the opening pressure chamber. When the exhaust-gas brake is operated, vacuum is applied to the closing pressure chamber of the EGR control valve to increase the force required to open the EGR control valve. That is, when a vacuum is applied to the closing pressure chamber of the EGR control valve, the force required to open the EGR control valve becomes the sum of the closing force of the spring inside the opening pressure chamber and the force of the vacuum applied to the closing pressure chamber. The force of the vacuum is due to the pressure difference between the atmospheric pressure and the vacuum. The sum of the closing force of the spring and the force of the vacuum is greater than normal force. Therefore, if backpressure from the exhaust-gas passage is applied to the valve of the EGR control valve when the exhaust-gas brake is operated, the EGR control valve will not open.

However, it is necessary to provide a source of high vacuum to the closing pressure chamber of the EGR control valve, in the device proposed in the Jajpanese Unexamined Utility Model Publication No. 63-79463. Further, it is also necessary to provide a vacuum switching valve (VSV) which applies a vacuum, from the vacuum source, to the opening pressure chamber when the exhaust-gas brake is not operated but the EGR device is operated, and which applies the vaccuum to the closing pressure chamber when the exhaust-gas brake is operated.

SUMMARY OF THE INVENTION

An object of the present invention is to provide an EGR device for an internal combustion engine equipped with an exhaust-gas brake downstream of an EGR passage, that realizes an sufficient exhaust-gas braking force when the exhaust-gas brake is operated by setting the force required to open the EGR control valve of the EGR device higher than the same to open the exhaust valve.

According to one aspect of the present invention, there is provided an EGR device, for an internal combustion engine equipped with an exhaust-gas brake device, which temporarily shuts off the flow of ex-

haust-gas within the exhaust passage and an EGR device which returns part of the exhaust-gas, from the exhaust pipe upstream of the exhaust-gas brake device, to the air-intake manifold, wherein the pressure required to open the exhaust valve is set to a value which provides a suitable exhaust-gas braking force and is set lower than the pressure required to open the EGR control valve of the EGR device.

In an internal combustion engine according to the present invention, the exhaust valves of cylinders that are in the intake cycle open at a lower pressure than the EGR control valve when the exhaust-gas brake is operated and the backpressure on the upstream side from the exhaust-gas brake valve rises, since the valve opening pressure of the exhaust valve is set to a value which provides a suitable exhaust-gas braking force and is lower than the pressure required to opne the EGR control valve of the EGR device. As a result, when the exhaust-gas brake operates, the EGR control valve does not open, and there is no leakage of exhaust-gas towards the air-intake manifold side and a suitable exhaust-gas braking force is provided.

In this way, the invention realizes a suitable exhaust-gas braking force in the internal combustion engine equipped with an EGR device and the exhaust brake.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more clearly understood from the description as set forth below with reference to the accompanying drawings, wherein:

Fig. 1 shows the overall configuration of an EGR device of an internal combustion engine with an exhaust-gas brake according to the present invention;

Fig. 2 shows a comparison of the characteristics of the backpressures in accordance with the valve opening pressures required to open an EGR control valve and an exhaust valve;

Fig. 3 is a configuration diagram which includes a cross-sectional view showing the details of the EGR control valve and the exhaust valve of the internal combustion engine with the exhaust-gas brake shown in Fig. 1; and

Fig. 4 is a graph which explains the change in backpressure characteristic with respect to the magnitude of the pressure required to open the exhaust-gas brake valve.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

A detailed description of an embodiment of present invention will follow, with reference to the attached drawings.

Figure 1 shows the overall configuration of an EGR device of an internal combustion engine with an exhaust-gas brake according to the present invention. In Fig. 1, reference numeral 1 denotes a 4-cylinder internal combustion engine, 2 denotes an air-intake manifold, 3 denotes an exhaust manifold, 4 denotes an exhaust passage, 5 denotes an exhaust-gas brake device having a exhaust-gas control valve 51 provided within the exhaust-gas passage 4, 6 denotes a muffler, 7 denotes an exhaust-gas recirculation passage (EGR passage) which brings exhaust-gas from the exhaust manifold 3 to the air-intake manifold 2, 8 denotes an EGR control valve, 9 denotes a vacuum pump, 10 denotes a control circuit, 11 and 12 denote control valves which are open/close controlled by the control circuit 10, and 13 denotes a vacuum intake pipe. The vacuum intake pipe 13 supplies vacuum from the vacuum pump 9 to the exhaust-gas brake device 5 via the control valve 11 and the EGR control valve 8 via the control valve 12.

The EGR control valve 8 is opened when vacuum from the vacuum pump 9 is brought in through the vacuum intake pipe 13 via the control valve 12, after the the control valve 12 is opened by a signal from the control circuit 10. When the EGR control valve is opened, exhaust-gas is returned, from exhaust-gas manifold 3 via the EGR passage 7, to air-intake manifold 2, thereby reducing the amount of NOx in the exhaust-gas.

The exhaust-gas brake device 5 is operated when the control circuit 10 detects a reduction in the speed of the vehicle. When the control circuit 10 detects a reduction in the speed of the vehicle, the control circuit 10 sends a signal to open the control valve 11. After the the control valve 11 is opened, vacuum from the vacuum pump 9 is applied to the exhaust-gas brake device 5, through the vacuum intake pipe 13, to close the exhaust-gas control valve 51. The closure of the exhaust-gas control valve 51 causes exhaust-gas to be trapped in the exhaust-gas pipe 4 and within the EGR pipe 7, thereby increasing the backpressure. When the backpressure is increased, the pumping resistance of the engine piston increases to act as a brake.

In the exhaust-gas brake device 5 which operates as described above, when the exhaust-gas-control valve 51 is closed, and the backpressure in the exhaust-gas passage 4 and inside the EGR passage 7 continues to increase, the exhaust valves (not shown in the drawing) of the cylinders of the internal combustion engine 1 which are in the intake cycle, and the EGR control valve 8, are caused to open by the backpressure. Figure 2 shows the characteristic of the backpressures in accordacnce with the valve opening pressures required to open the EGR control valve 8 and the the exhaust valve shown in Fig. 1. In this embodiment, the pressure required to open the exhaust valve 5 by the backpressure is set higher than the lower limit value at which it is possible to achieve ex-

haust-gas-braking force, and the pressure required to open the EGR control valve 8 by the backpressure is set higher than the same to open the exhaust valve 5.

Figure 3 is a configuration diagram which includes a cross-sectional view that shows the details of an EGR control valve 8 and an exhaust valve 30 which is provided in the internal combustion engine 1, with the exhaust-gas brake shown in Fig. 1. In Fig. 3, reference numeral 14 denotes an intake passage which is connected to an air-intake manifold 2, 15 denotes an air-intake-control valve which is provided within the air-intake passage 14, 16 denotes an air-intake port, 17 denotes a combustion chamber, 18 denotes a piston, 19 denotes an exhaust port, and 20 denotes an air-intake valve.

Exhaust valve 30 has a valve 31 which opens and closes the exhaust port 19, a spring 32 which applies force in the direction which causes the valve 31 to close the exhaust port 19, and an exhaust cam 33 for the purpose of opening the valve 31 in opposition to the force of the spring 32. The EGR control valve 8 is divided into a valve part 8A and a valve-drive part 8B. In the housing 80 of the valve part 8A, there is provided a valve 81 which opens and closes the EGR passage 7, and a valve stem 82 which is mounted on the valve 81. The valve drive part 8B has a housing 88 which is separated into an atmospheric pressure chamber 88A and a vacuum chamber 88B by a diaphragm 83. A spring 84 is located inside the vacuum chamber 88B. The end of the valve stem 82 is connected to the diaphragm 83 inside the atmospheric pressure chamber 88A. The spring 84 applies force to the diaphragm 83 in a direction that causes the valve 81 to close.

When the control valve 12, shown in Fig. 1, is opened by the control circuit 10, vacuum generated in vacuum pump 9 is applied to the vacuum chamber 88B via vacuum intake pipe 13. The diaphragm 83 moves in the direction of the vacuum chamber 88B against the force of spring 84 due to the vacuum in the vacuum chamber 88B. The movement of the diaphragm 83 described above causes the valve 81 to open, thus causing exhaust-gas to return to the air-intake manifold 2 via the EGR passage 7.

Furthermore, when the exhaust-gas control valve 51 in the exhaust-gas brake device 5 is closed, the pressure within the exhaust-gas pipe 4 and the EGR passage 7 rises in a pulsating manner, as shown by the solid line B in Fig. 4, and then stabilizes at a given pressure. This pulsation is caused by a reverse flow of exhaust-gas trapped within the exhaust-gas passage 4, to the combustion chamber 17 and a normal flow thereof from the combustion chamber 17 to the exhaust-gas passage 4. The reverse flow occurs when the valve 31 opens at the beginning of the exhaust cycle, and this causes a drop in pressure. Contrary to this, the normal flow occurs when the piston 18 rises to cause compression during the progress of the exhaust cycle, and this causes an increase in the pressure.

The reason the overall rise in pressure stops after the passage of time is that when the backpressure reaches the closing force set on the spring 32 of the exhaust valve 30, the valve 31 of the exhaust valve 30 of the cylinder in the air-intake cycle is pushed downward by the backpressure. The opening of the exhaust valve 30 of the cylinder in the air-intake cycle causes the exhaust-gas to escape to the combustion chamber 17 of the cylinder in the air-intake cycle.

In this condition, if the spring 32 is made sufficiently strong so as to increase the valve opening pressure of the exhaust valve 30, the pressure at which this backpressure stabilizes increases, as shown by the solid line A in Fig. 4. If the spring 32 of the exhaust valve 30 is made still stronger, the backpressure rises higher, as shown by the dot-dash line C in Fig. 4.

Contrary to this, if the closing force set on the spring 84 of the EGR control valve 8 is lower than the closing force set on the spring 32 of the exhaust valve 30, the EGR control valve 8 opens at a lower pressure than the exhaust valve 30, when the exhaust control valve 51 closes the exhaust-gas passage 4 to cause a rise in backpressure. When the EGR control valve 8 opens at a lower pressure than the exhaust valve 30 when the exhaust-gas-brake device 5 is operated, the backpressure in the exhaust-gas passage 4 drops and the braking performance of the exhaust-gas brake falls.

For this reason, in this embodiment, as explained in Fig. 2, the opening pressure required to open the exhaust valve 30 is set to a value that provides a suitable exhaust braking performance. Under this condition, the closing force of the spring 84 of the EGR control valve 8 is set to a value higher than the closing force of the spring 32 of the exhaust valve 30 to prevent a reduction in the exhaust-gas braking performance due to the opening operation of the EGR control valve 8.

Examples of calculations of the valve-closing-force of the spring 32 of the exhaust valve 30 and the valve-closing-force of the spring 84 of the EGR control valve 8 are shown below. In the equations shown below, reference Dex denotes the surface diameter over which backpressure is applied to valve body 31 of exhaust valve 30 in the opening direction, Pex denotes the backpressure required when the exhaust-gas brake is operated (this value depends on the type of the vehicle), and Degr denotes the surface diameter over which backpressure is applied to valve 81 of the EGR control valve 8 in the opening direction.

If Fex is the valve-closing-force of the spring 32 of the exhaust valve 30, Fex is expressed by the following equation① :

$$Fex = [\pi \times (Dex)^2 \times Pex] \times 1/4 \qquad ①$$

If Fegr is the valve-closing-force of the spring 84 of EGR control valve 8, Fegr is expressed by the following equation ② :

$$Fegr \geqq [\pi \times (Degr)^2 \times Pex] \times 1/4 \qquad ②$$

By virtue of the equations ① and ②, the following relationship exists.

$$(Fegr / Fex) \geqq (Degr / Dex)^2 \qquad ③$$

This equation ③ can be rearranged as follows.

$$Fegr \geqq Fer \times (Degr / Dex)^2 \qquad ④$$

Therefore, the valve-closing-force Fegr of the spring 84 of the EGR control valve 8 should be determined so as to achieve the value of force determined according to the equation ④.

As described above, it is possible for the EGR device of an internal combustion engine with an exhaust-gas brake according to the present invention to control the backpressure to produce a suitable exhaust brake force when the exhaust-gas-brake device 5 is operated, because the exhaust valve 30 opens at a lower backpressure than the EGR control valve 8. In this manner, it is not necessary for the EGR device of the present invention to have a powerful drive source to increase the opening force of the EGR control valve 8, or a vacuum switching device, since the present invention only adjusts the set value of the valve-opening-pressure of the exhaust valve 30 (=valve-closing-force of the spring 32 of the exhaust valve 30) and the EGR valve 8 (=valve-closing-force of the spring 84 of the EGR valve 8) which already exist on the internal combustion engine.

Accordingly, the EGR device of the present invention produces a suitable exhaust-gas-braking force in an internal combustion engine using an exhaust-gas brake device.

In addition, because the above does not necessitate a powerful drive source, to increase the opening force of the EGR control valve, or a vacuum switching means, there is no increase in cosd.

In an internal combustion engine having an exhaust-gas brake device in exhaust-gas pipe and an EGR device which returns part of the exhaust-gas from the exhaust-gas pipe upstream from this exhaust-gas brake device to the air-intake manifold, a suitable exhaust-gas-brake force can be obtained by setting the opening pressure required to open the exhaust-gas valve to a value which allows the production of a suitable exhaust-gas-braking force but lower than the opening pressure required to open the EGR control valve of EGR device. As a result, when the exhaust-gas brake operates, the leakage of exhaust-gas into the air-intake manifold is eliminated, and the desired exhaust-gas-braking force is achieved.

Claims

1. An EGR device, for an internal combustion engine (1) having an exhaust-gas brake device (5) which temporarily shuts off the flow of exhaust-gas within an exhaust-gas passage (4), comprised of an EGR control valve (8) and an EGR passage (7) which returns part of said exhaust-gas from said exhaust passage (4) upstream of said exhaust-gas brake device (5) to an air-intake manifold (2) of said engine (1), said EGR device being characterized in that:

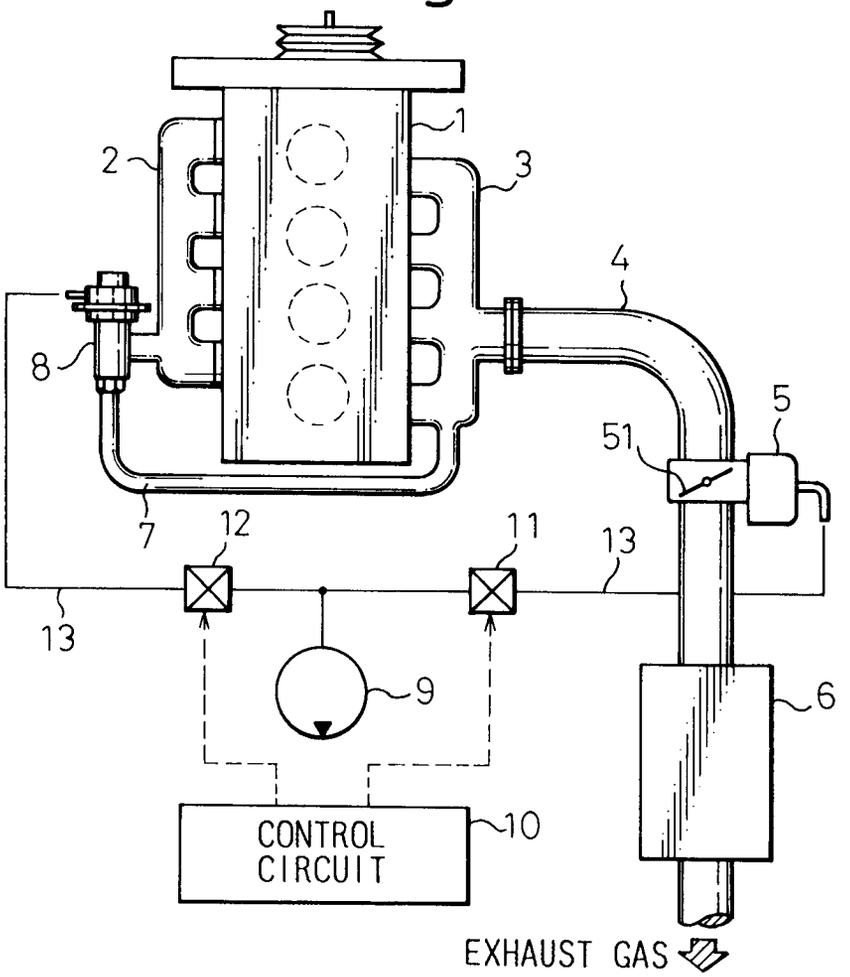
   the opening pressure required to open said exhaust valves (30) of said engine (1), which exhaust the combustion gas from a combustion chamber (17) of said engine (1) to said exhaust passage (4), is set to a value which produces a suitable exhaust-gas-braking force; and

   the opening pressure required to open said EGR control valve (8) is set to a value higher than the opening pressure required to open said exhaust valve (30).

2. An EGR device for an internal combustion engine as set forth in claim 1, wherein said exhaust-gas brake device (5) and said EGR control valve (8) are controlled by a vacuum generated by a vacuum pump (9).

3. An EGR device for an internal combustion engine as set forth in claim 1 or 2, wherein said opening pressure required to open said exhaust valves (30) is set by a valve-closing-force of a spring (32) provided in said exhaust valve (30), and said opening pressure required to open said EGR control valve (8) is set by a valve-closing-force of a spring (84) provided in said EGR control valve (8).

Fig.1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CONTROL CIRCUIT
EXHAUST GAS

Fig.2

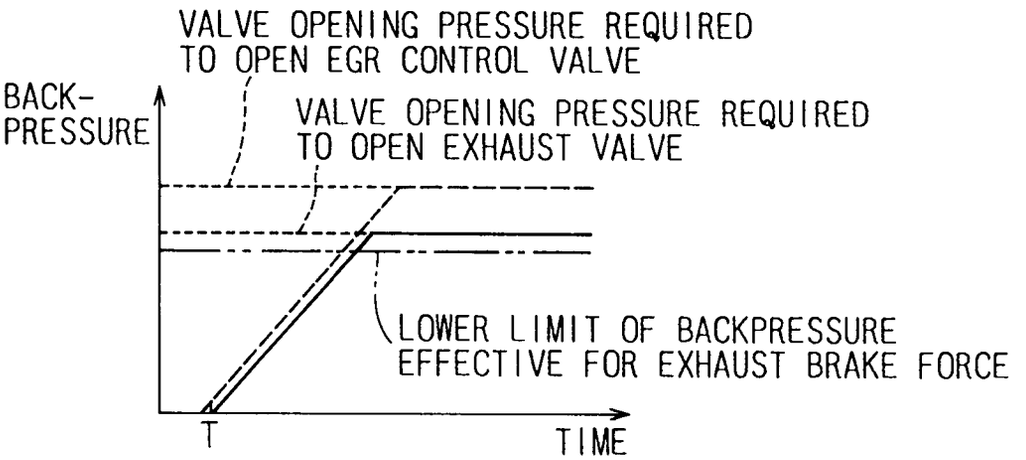
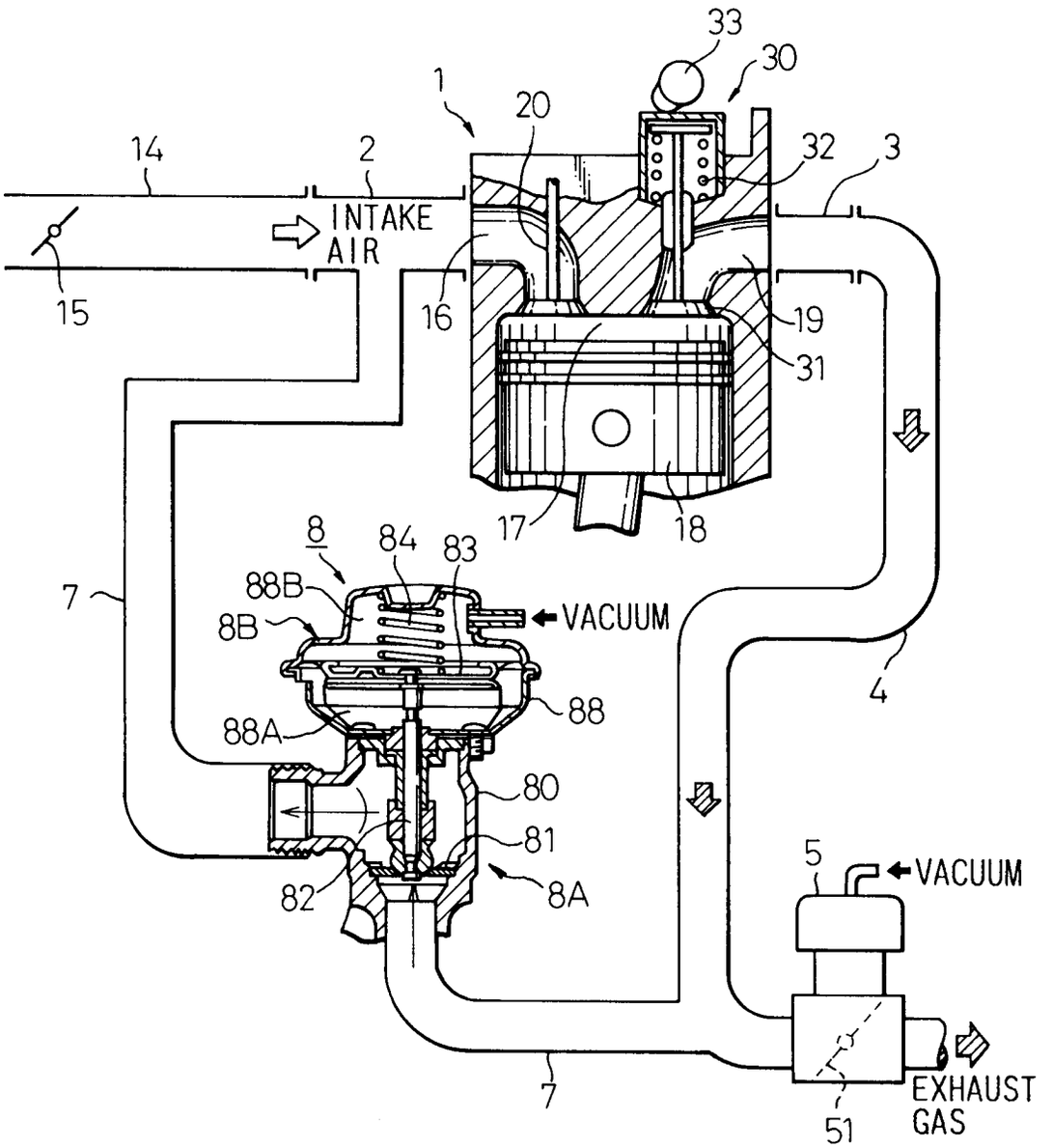

VALVE OPENING PRESSURE REQUIRED TO OPEN EGR CONTROL VALVE
BACK-PRESSURE
VALVE OPENING PRESSURE REQUIRED TO OPEN EXHAUST VALVE
LOWER LIMIT OF BACKPRESSURE EFFECTIVE FOR EXHAUST BRAKE FORCE
T
TIME

Fig. 3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INTAKE AIR
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31
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8
84
83
88B
8B
VACUUM
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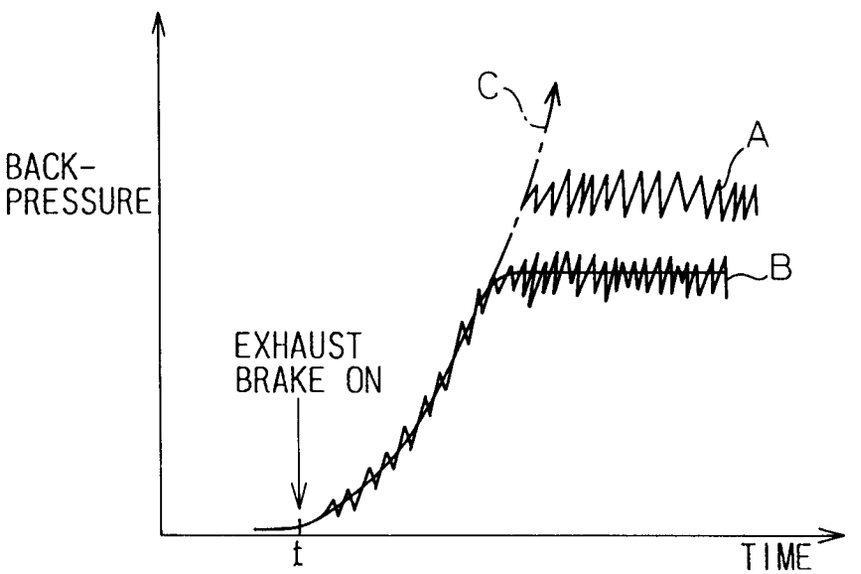
88
88A
80
81
82
8A
4
5
VACUUM
7
51
EXHAUST GAS

Fig.4



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EUROPEAN SEARCH REPORT

Application Number
EP 94 11 8145

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)
A,D	JP-U-6 379 463 (...) * figures 1,5 *	1-3	F02M25/07 F02D9/06
A	PATENT ABSTRACTS OF JAPAN vol. 16, no. 69 (M-1212) 20 February 1992 & JP-A-03 258 960 (TOYOTA MOTOR CORP.) 19 November 1991 * abstract *	1-3	
A	PATENT ABSTRACTS OF JAPAN vol. 10, no. 114 (M-473) 26 April 1986 & JP-A-60 243 329 (MITSUBISHI JIDOSHA KOGYO KK) 3 December 1985 * abstract *	1	
A	PATENT ABSTRACTS OF JAPAN vol. 17, no. 604 (M-1506) 8 November 1993 & JP-A-05 180 010 (FUJI OOZX KK) 20 July 1993 * abstract *	1	
A,P	PATENT ABSTRACTS OF JAPAN vol. 18, no. 628 (M-1713) 30 November 1994 & JP-A-06 241 071 (JIDOSHA KIKI CO LTD) 30 August 1994 * abstract *		TECHNICAL FIELDS SEARCHED (Int.Cl.6) F02M F02D
A,P	PATENT ABSTRACTS OF JAPAN vol. 18, no. 465 (M-1665) 30 August 1994 & JP-A-06 147 025 (TOYOTA MOTOR CORP.) 27 May 1994 * abstract *		
A	PATENT ABSTRACTS OF JAPAN vol. 5, no. 43 (M-060) 23 March 1981 & JP-A-56 000 528 (AISIN SEIKI CO LTD) 7 January 1981 * abstract *	2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	5 April 1995	Alconchel y Ungria,J

CATEGORY OF CITED DOCUMENTS

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