(12) UK Patent Application (19) GB (11) 2 165 584 A

(43) Application published 16 Apr 1986

(21) Application No 8520283

(22) Date of filing 13 Aug 1985

(30) Priority data
(31) 3429909 (32) 14 Aug 1984 (33) DE
3444877 8 Dec 1984

(51) INT CL[4]
F02D 37/00 11/08 F02M 25/06

(52) Domestic classification
F1B B120 B140 B204 B210 B228 B234 B236 B300 BB

(56) Documents cited
GB A 2083553 EP A2 0079581 US 4446840
GB A 2075592 US 4452217 US 4369753

(58) Field of search
F1B

(71) Applicant
Robert Bosch GmbH (FR Germany),
Postfach 50, 7000 Stuttgart 1, Federal Republic of Germany

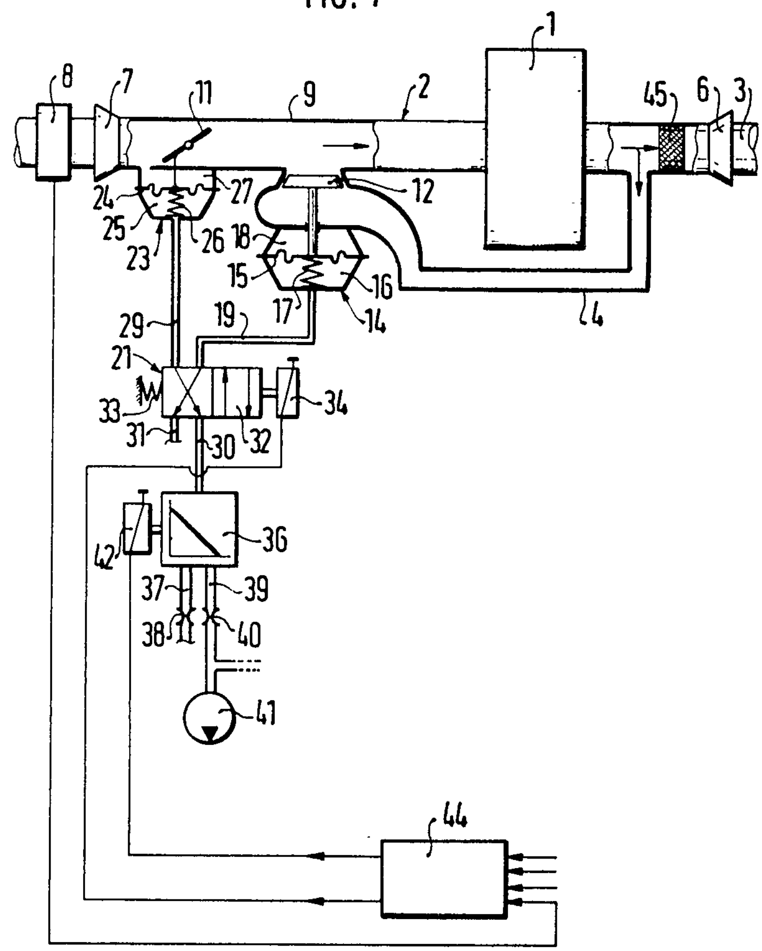
(72) Inventors
Gerhard Stumpp
Wolf Wessel

(74) Agent and/or Address for Service
W P Thompson & Co,
Coopers Building, Church Street, Liverpool L1 3AB

(54) Control of I.C. engine exhaust recirculation and air intake

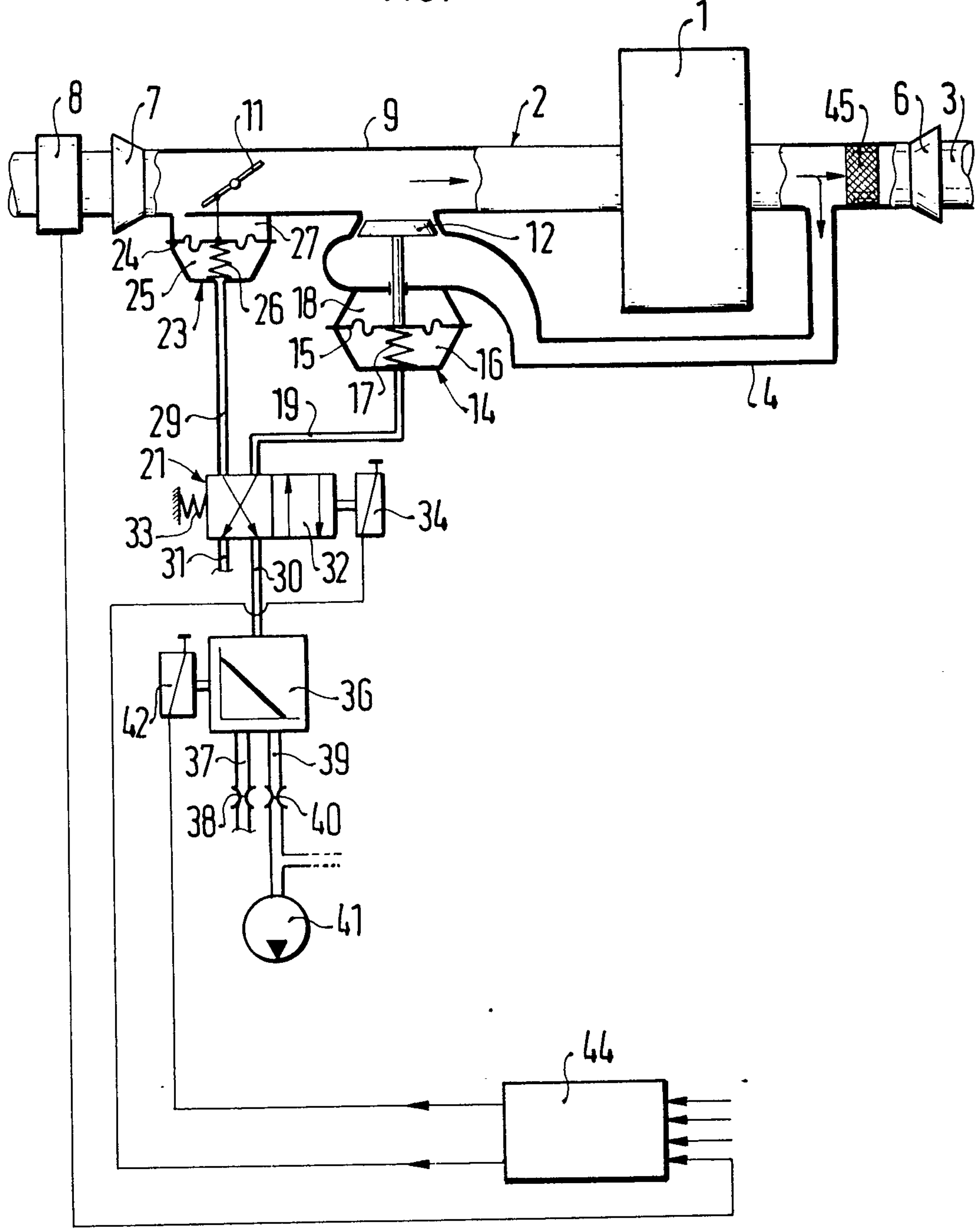
(57) A diesel engine (1) has an exhaust gas recirculation control element (12) actuated by a first servomotor (14) and a butterfly valve (11) disposed in the intake manifold (9) of the internal combustin engine and actuated by a second servomotor (23). The two servomotors are actuated by pressure media and are provided with restoring means (17, 26) such that, when pressure is equalized at the servomotors, the butterfly valve (11) is brought into a position in which it opens the intake manifold (9) and the exhaust gas recirculation control element (12) is brought into a position in which it closes the exhaust gas recirculation line (4). Control of the servomotors is effected by the control pressure or pressures produced by a signal pressure converter (36) or respective signal pressure converters (Figs. 2 and 3) in response to engine operating conditions. A change-over valve (21) may determine in which of the servomotors the control pressure is operative.

FIG. 1



GB 2 165 584 A

FIG. 1


1
2
3
4
6
7
8
9
11
12
14
15
16
17
18
19
21
23
24
25
26
27
29
30
31
32
33
34
36
37
38
39
40
41
42
44
45

2165584

FIG. 2

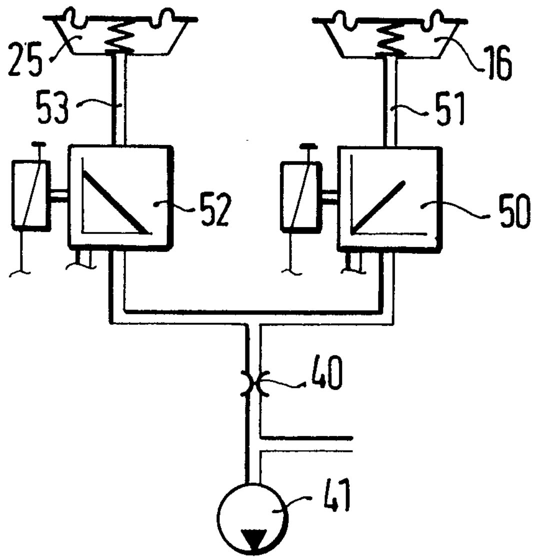


FIG. 3

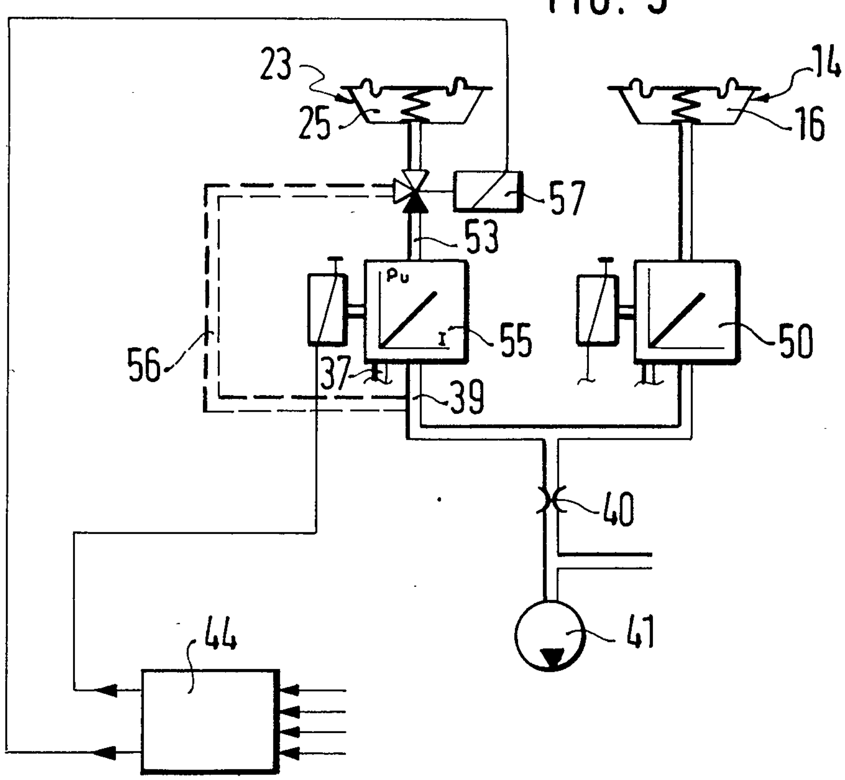


FIG. 4

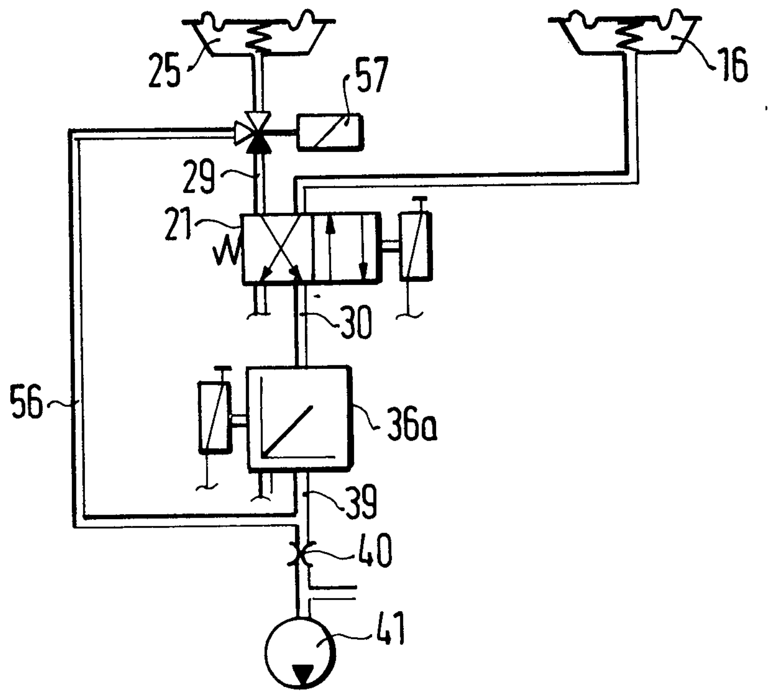
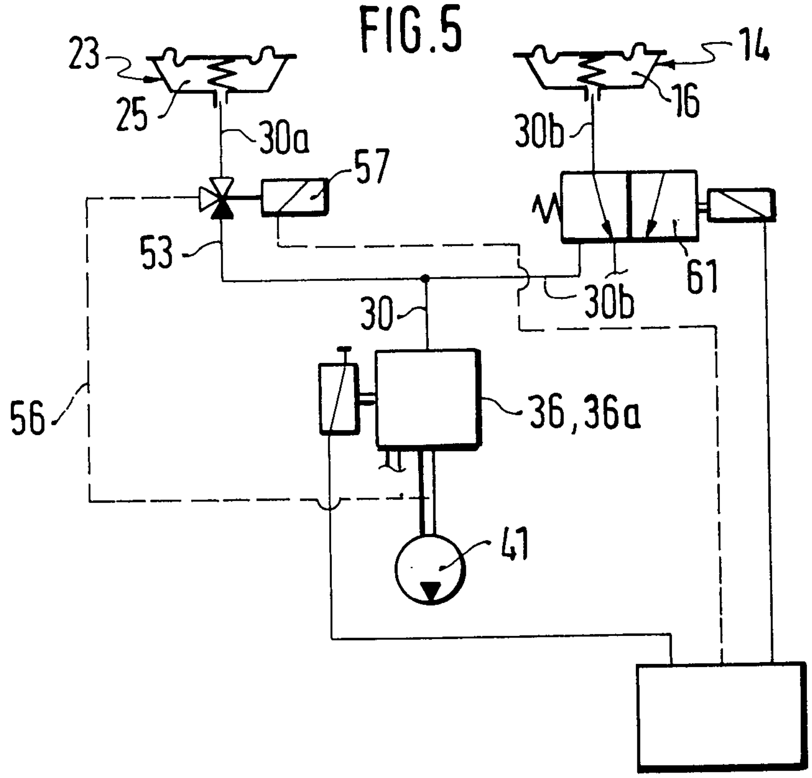

25
57
16
29
21
30
56
36a
39
40
41

FIG. 5


23
25
14
16
30a
57
30b
53
61
30b
30
56
36, 36a
41

SPECIFICATION

Control system for an internal combustion engine and method of controlling gases

The invention relates to a control system for an internal combustion engine having exhaust gas recirculation and to a method of controlling gases in an internal combustion engine.

In such a control system known from U.S.A. Patent Specification No. 4 177 777 the quantity of air inducted by the internal combustion engine is measured by means of an air quantity meter, and the control pressure of a pneumatically actuated exhaust gas recirculation valve is varied in conformity with the air quantity signal, and, if necessary, with further dependence upon other operating parameters, thus controlling the quantity of recirculated exhaust gas. In another control system of this type, known from Published German Patent Specification No. 31 45 527, the recirculated quantity of exhaust gas is regulated according to the difference between the actual quantity of air which is fed and the value of desired quantity of air derived from various parameters, including load. Correction of the actual quantity of air is carried out by changing the recirculated quantity of exhaust gas in free-inducting diesel engine. The control element for the recirculated quantities of exhaust gas is actuated by means of a pneumatic control pressure medium which is fed from a pressure converter into the control pressure chamber of the servomotor of this control element. In the known control devices, the pressure converter comprises two two-port, two-position solenoid valves, by means of which the control pressure chamber may be connected either to the atmosphere as a reference pressure source or to a vacuum source. Control of the solenoid valves can be on-off or analog.

In such a control system, only the quantity of the recirculated exhaust gas is regulated precisely with the aim of optimum combustion with the highest possible exhaust gas recirculation rate in order to reduce the nitrogen oxide, (NOx) pollutant emission. The fuel-air ratio is maintained accurately by the quantity of fresh air controlled by means of the quantity of recirculated exhaust gas at a given load or fuel quantity, thus also keeping the proportion of the hydrocarbon (HC) and carbon monoxide (CO) and soot in the exhaust gas low. However, such a system does not fulfil the other requirements of a self-igniting internal combustion engine. In particular, increased soot emission in the exhaust gas must be expected in a self-igniting internal combustion engine when special measures are not taken, and therefore care must be taken that this soot does not reach the atmosphere.

The present invention resides in a control system for a self-igniting internal combustion engine having an air-intake system, an exhaust gas collection system, and an exhaust gas recirculation line leading from the latter back to the intake system, said system comprising an exhaust gas recirculation control element disposed in the exhaust gas recirculation line and subjected to a restoring force in the closing direction; a first pressure medium actuated servomotor for adjusting said recirculation control element; a throttle element disposed in the intake system upstream of the juncture with the recirculation line and subjected in the opening direction to a restoring force; a second pressure medium actuated servomotor for adjusting the intake throttle element, the first and second servomotors each having a movable wall coupled respectively to the recirculation control element or the intake throttle element and separating a respective first or second control pressure chamber from a respective first or second reference pressure chamber; a control pressure converter common to the first and second servomotors or a separate control pressure converter for each servomotor, the or each control pressure converter being adapted to derive a control pressure from the pressures of a first pressure source and a second pressure source, which control pressure or pressures is or are to be applied to both of the first and second control pressure chambers of the servomotors or respectively to the first and second control pressure chambers; and a control device for producing a control signal for the or each control pressure converter in dependence upon at least one engine operating parameter.

The invention includes a method of controlling gases comprising, on the one hand, air and, on the other hand, recirculated quantities of exhaust gas fed to the combustion chamber or chambers of a self-igniting internal combustion engine, in which the recirculation quantity of exhaust gas is controlled by an exhaust gas recirculation control element actuated by a controllable pressure medium, and in which, in a first operating range, and with recirculated exhaust gas, the air is fed unrestrictedly and, in a second operating range, the air fed in is also controlled by a throttle element actuated by a controllable pressure medium, and the exhaust gas recirculation is discontinued.

This has the advantage that, with the aid of a controlled butterfly valve and with minimum outlay, the quantity of inducted air can be controlled in dependence upon operating parameters within ranges of operation of the internal combustion engine in which exhaust gas recirculation does not take place. Correspondingly controlled throttling of the quantity of intake air thereby reduces sound emitted by the self-igniting internal combustion engine when idling, stabilizes idling, increases the exhaust gas temperature with the aim of burning off soot collected in a soot filter disposed in the exhaust gas sytem and, if required, can bring the internal combustion engine to a complete stop.

Advantageously, a single pneumatic pressure converter can be provided, which can be used selectively to control the first servomotor or the second servomotor, only one inexpensive change-over valve having only a low current requirement being additionally required for this purpose. This reduces the expenditure required for actuating the throttle element in the intake system. Additionally, the quantity of pressure medium required is also kept low.

The arrangement can be such that the throttle element in the intake system remains operative, even in ranges of operation in which exhaust gas recirculation takes place and thus may be controlled in such a way that the control of the recirculated quantity of exhaust gas is stabilized by throttling the quantity of intake air. The intake throttle element can be used to influence the pressure differential, which causes delivery, at the exhaust gas recirculation control element, and accurately to regulate the rate of exhaust gas recirculation. In those ranges of operation in which no exhaust gas racirculation takes place, the device operates in the same way as that stated above.

The control system may be so constructed that, in the event of current supply failure, the exhaust gas recirculation control element closes the exhaust gas line, in that the reference pressure (such as atmospheric pressure) acts on the control pressure chamber of the first servomotor to reinforce the effect of the restoring force acting in the closing direction on the movable wall. This fulfils a safety function in the control system. At the same time, when an electrically controlled valve between the pressure converter and the first control pressure chamber is switched off, the control pressure chamber of the second servomotor is connected to the pressure converter and, *via* the pressure converter, to the first pressure source, so that, in such a case, the throttle element in the intake system is also moved into the closed position. This fulfils a safety function.

In an analogous way, in the case of power failure, the pressure converter, when in the "off" state, can connect the control pressure chamber to the first pressure source and cause the throttle element in the intake system to close.

The first pressure source can be a source of vacuum, but it can alternatively be a source of superatmospheric pressure obtained from an engine-driven pump. Thus, in the latter case, it can be ensured that, upon starting, the throttle element in the intake system is open, since in an internal combustion engine which is not yet running, the first pressure source is then not yet available and the control pressure chamber of the servomotor is subjected to the atmospheric reference presure to assist the restoring force acting in the open direction of the throttle element. The exhaust gas recirculation line is closed in this case.

In another arrangement of control system according to the invention, the first servomotor and the second servomotor are each associated with a respective pressure converter which is so designed that, when in the "off" state, it supplies the pressure control chamber of the servomotors with the reference pressure. Since, in the case of such embodiment, the pressure converters would have to be live in order to stop the internal combustion engine, the pressure control chamber of the second servomotor, which controls the throttle element in the intake system, is connected to a line which is directly connected to the first pressure source and in which is disposed a valve which is open when it is in its non-energised state. Here, once again a safety function is fulfilled in that the internal combustion engine can be stopped when the valve is in its non-energized state. The same effect is also achieved if this measure is used in a control device operating with only one pressure converter, wherein the pressure converter, when in the "off" state, supplies the reference pressure as a control pressure.

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

Fig.1 is a diagrammatic representation of a first embodiment of control system according to the invention, having only a single pressure converter connected to an electrically controlled valve

Fig.2 shows a detail of a control system having two pressure converters, operating in opposite senses,

Fig.3 shows a modification to the embodiment of Fig.2 having two pressure converters operating in the same sense and having a bypass line for bypassing one pressure converter,

Fig.4 shows part of a fourth embodiment of the invention having only one pressure converter and having a by-pass line for bypassing one pressure converter, and

Fig.5 shows part of a fifth embodiment of the invention having only one pressure converter which is connectible by means of a change-over valve to the other control pressure chamber.

The first embodiment of the invention is illustrated in Fig.1 as a schematic diagram. This Fig. shows a self-igniting (Diesel) internal combustion engine 1 with an intake system 2 and an exhaust gas collector system 3. An exhaust gas recirculation line 4 leads from this system back to the intake pipe 9 of the intake system 2. Only one continuous pipe is shown to represent the intake manifold, which usually consists of the intake pipe 9 and other inlet manifold branches connected to it. The internal combustion engine can operate with pressure-charging, for example with an exhaust turbo-supercharger, wherein an exhaust gas turbine 6 is installed in the exhaust gas collection system and an air compressor 7 in the intake system, said air compressor being driven by the exhaust gas turbine. At the inlet to the intake system, an air quantity meter 8 is provided, at least upstream from the junction of the exhaust gas recirculation line 4 with the intake pipe 9. Said air quantity meter 8 can be connected serially either before or after the air compressor 7. Furthermore, in the intake pipe 9 of the intake system upstream of the junction with the exhaust gas recirculation line 4 there is provided a throttle element 11, for example in the shape of a butterfly valve, by means of which the intake cross section of the intake pipe 9 and thus the quantity of air delivered to the internal combustion engine can be altered.

At the point of entry of the exhaust gas recirculation line 4 into the intake pipe 9, an exhaust gas recirculation control element 12 is provided, the position of which is used to alter the cross-sectional area of the exhaust gas recirculation line. The exhaust gas recirculation control element 12 is represented symbolically in the diagram as a poppet valve, but it can also have other forms. It is actuated by a first servomotor 14 to which it is connected and which has a movable wall 15, shown here as a regulating diaphragm. The movable wall 15 defines, in the housing of the servomotor 14, a first pressure control chamber 16, in which is fixed a return spring 17 which acts on the movable wall 15. A second pressure chamber 18 on the other side of the movable wall 15 is connected to the ambient air, while a control pressure line 19 leads from the first control pressure chamber to one port of an electrically controlled change-over valve 21.

The throttle element 11, which is an air throttle element, is actuated by a second servomotor 23 and, in addition, is connected mechanically to a movable wall 24 of this servomotor. This movable wall defines in the housing of the second servomotor 23 a second control pressure chamber 25, in which is also fixed a return spring 26 acting on the movable wall 24. On the other side of the movable wall 24 is a pressure chamber 27 which is subjected to atmospheric pressure. The movable wall 24 of the second servomotor 23 is connected to the air throttle element 11 in such a way that the element is brought into the open position by the action of the return spring 26, whereas the movable wall 15 of the first servomotor 14 is connected to the exhaust gas recirculation control element 12 in such a way that the return spring 17 acts on the element 12 in a direction to close the exhaust gas recirculation line 4.

A second control pressure line 29 runs from the second control pressure chamber 25 to another port of the electrically controlled change-over valve 21. The change-over valve 21 has four ports, namely the above-mentioned ports connected to the control pressure lines 19 and 29 a port connected to a control pressure supply line 30 and a port 31, which is connected to a reference pressure source, in the example shown to the ambient air under atmospheric pressure. The electrically controlled change-over valve 21 has a valve member 32, which is moved by means of a return spring 33 into a first preferred position and by means of an electrically controlled signal into a second position. The valve member 32 may be actuated in the usual way by an electromagnet 34 or in some other electrically controlled way, if necessary with the air of servo means. The valve member 32 is so designed that, in its original position shown and with the electromagnet 34 not energised, it connects the control pressure line 19 to the port 31 and the control pressure line 29 to the control pressure supply line 30.

The control pressure supply line 30 branches off from an electrically controlled pressure converter 36, which is represented symbolically in the drawings. This may, for example, take the form of one three-port, two-position valve or two two-port two-position valves or a proportionally operating valve. Such converters are generally known, for example, from German patent specification No. 31 45 527 or U.S.A.Patent No. 4 177 777 and do not need to be described here in great detail. The electrically controlled pressure converter 36, which, in the example shown, may also be an electropneumatic converter (EPC), has three ports, the above-mentioned port connected to the control pressure supply line 30, a reference pressure port 37, which leads, if necessary by way of a throttle 38, to the ambient air, and a pressure medium port 39, which is connected via a second throttle 40 to a pressure medium source 41, which may be a vacuum pump. An actuator 42, for example an electro-magnet coil, of the pressure converter 36, is connected to a control device 44, which evaluates the selected number of engine parameter signals, such as engine speed, fuel quantity and air quantity and sends the corresponding control signals to the actuator 42. The actuator 42 may, for example, be controlled cylically with variable pulse width, thus alternatingly connecting the reference pressure port 37 or the pressure medium port 39 to the control-pressure supply line 30. In another refinement, however, this control may be effected in an analogue manner by altering the cross sections of the reference pressure port and pressure medium port. The functional diagram of the pressure converter 36 is shown on the converter in the drawing, and it follows from this diagram that, when no current is acting on the actuator 42, the vacuum p_u delivered at the pressure medium port 39 is fed to the control pressure supply line 30, while the reference pressure port 37 is closed. In the case of full current supply, however, the reference pressure port 37 is fully open and the pressure medium port 39 is fully closed. The operating characteristic can be adapted via throttles 38 and 40.

The electrically controlled change-over valve 21 continues to be controlled by the control device 44. The control device 44 distinguishes, on the basis of the control signal of the engine parameters transmitted to it, between two operating conditions; a first operating condition, in which exhaust gas recirculation (ECR) takes place, and a second operating condition, in which exhaust gas recirculation is prevented. This second operating condition corresponds amongst other things to the idle state of the internal combustion engine, a state in which it is necessary to burn off soot in the soot filter 45 or to stop the internal combustion engine. This distinction may be effected, for example, by way of a load signal or a signal from the fuel quantity delivered to the internal combustion engine or by other representative paramaters such as pressure drop at the soot filter.

With the change-over valve 21 in the position shown in Fig. 1, the internal combustion engine is in the above-mentioned second operating condition. In the first operating condition, the valve member 32 is displaced against the force of the spring 33, and the control pressure line 19 is connected to the control pressure supply line 30, while the second control pressure chamber 25 is vented via the second control pressure line 29 and the port 31. In this condition, atmospheric pressure, that is the same pressure as that in the pressure chamber 27, prevails in the sscond pressure control chamber 25, so that the movable wall 24, being subjected to the force of the spring 26, moves the butterfly valve 11 to the fully open position. The first control pressure chamber 16 of the first servomotor 14, however, is subjected to the variable control pressure delivered by the pressure converter 36. The internal combustion engine, which is now free-inducting, is supplied with both air and exhaust gas in controlled quantities, whereof the proportion of air in the gas fed into the combustion chambers of the internal combustion engine is altered by means of the exhaust gas quantity control. Using the air quantity signal transmitted by the air quantity meter 8 and the fuel quantity signal and by means of the control device 44, a given air/fuel ratio is fixed by changing the exhaust gas recirculation rate. The internal combustion engine always operates with complete filling, wherein maximum amounts of recirculated exhaust gas may be fed, as residual filling of the combustion chambers is effected with exhaust gas. As is known, exhaust gas recirculation has the effect of reducing the peak temperatures in the combustion chamber, thus reducing the proportion of nitrogen oxides, NO_x in the emitted exhaust gas. With the aid of stored performance characteristic and the access parameters to these characteristics, such as speed, fuel quantity, temperature and others, the quantity of exhaust gas can be controlled accurately over the entire operating range with exhaust gas recirculation. The temperature factor allows in particular for the cold internal combustion engine and the necessary fuel-air ratios for trouble-free operation of the internal combustion engine.

In the above-mentioned second operating condition, the exhaust gas recirculation is interrupted, as, in certain ranges, the internal combusion engine should operate with reduced filling of the engine cylinders. For the internal combustion engine to run smoothly, it is advantageous, particularly during idling, to have a low level of gas filling of the engine cylinders. Furthermore, when the cylinder filling is low, the exhaust gas temperature rises, so that soot collected in the soot filter burns more easily. In this second operating condition, the electrically controlled change-over valve 21 is in the "off" state and the valve member 32 takes up the position shown in Fig. 1. In this position, the first control pressure chamber 16 is connected to the ambient air and has the same pressure level as the pressure chamber 18, so that the movable wall 15, under the influence of the return spring 17, moves the exhaust gas recirculation control element 12 into its closed position. At the same time, however, the control pressure created by the pressure converter 36 is fed to the second control pressure chamber 25 and then, by modulating the control pressure accordingly using the control device 44, the control pressure is used to move the butterfly valve 11 into the required position. In accordance with the parameters fed into the control device 44, the intake air is restricted to a greater or lesser extent to reduce idling noise during the idling operation of the internal combustion engine. This restriction affects the final compression level in the combustion chambers of the internal combustion engine and results in a low vibration level during engine running. The speed of the internal combustion engine may be input in the form of a feedback signal into a servo loop to control the butterfly valve.

In the second operating condition, in which no exhaust gas recirculation takes place, the exhaust gas temperature may also be increased by throttling using the butterfly valve 11, with the aim of burning free the soot filter 45 disposed in the exhaust gas system. Because of the high proportion of soot in the exhaust gas from self-igniting internal combustion engines, the pores of filters very rapidly become filled with deposits of soot, which increases the back pressure in the exhaust gas system. Such filters may either be replaced, or the soot collected may be burned off without having to replace the filter. The latter method has the recognizable advantage of simple maintenance. To remove the soot which has collected in the filter, the exhaust gas temperature in the second operating range may be increased with the aid of the butterfly valve 11 to such a level that the soot is burnt away. Advantageously, this also occurs with the use of catalytically effective parts of the filter, with the aim of lowering the ignition temperature.

A time factor in connection with the existence of the second operating condition may be used as a control parameter, or, likewise, the increase in back pressure or the fall in pressure at the filter. A further condition is that the internal combustion engine must have reached its operating temperature.

If the internal combustion engine has to be stopped, this may be done advantageously and in accordance with the solution according to the invention by way of the butterfly valve 11 which is moved into the closed position. To do this, the electrically controlled change-over valve 21 is switched off so that the control pressure line 29 is connected to the pressure converter 36. The pressure converter 36 is also switched off, so that the full vacuum from the pressure source 41 is fed *via* the change-over valve 21 into the second control pressure chamber 25, which results in the butterfly valve 11 closing. The same also happens when the control device 44 is in the non-energised state or switched off. This property ensures that the internal combustion engine is safely brought to rest even in the event of damage. When the internal combustion engine starts up, the fact that the vacuum pump 41 is not yet operating at this point means that no vacuum is available which could effect closing of the butterfly valve.

As a variant of the embodiment according to the invention shown in Fig.1, the embodiment in Fig.2 provides for a separate, electrically controlled pressure ccnverter for each of the servomotors. In place of the pressure converter 36 and the change-over valve 31 in Fig.1, there is a first pressure converter 50, whose control pressure supply line 51 is connected to the first control pressure chamber 16, and a second pressure converter 52, whose control pressure supply line 53 is connected to the second control pressure chamber 25. Both pressure converters 50 and 52 are supplied with vacuum from the same pressure medium source 41 by way of a decoupling second throttle 40. The ambient air is used as the reference pressure source. The first pressure converter 15 is designed such that, in the nonenergised state, the reference pressure is fed by way of the control pressure supply line 51 to the first control pressure chamber 16, whereas, in the case of full current flow, the pressure of the vacuum source alone is fed into the first control pressure chamber 16. Correspondingly, when the pressure converter 50 is switched off, the exhaust gas recirculation control element moves into the closed position and exhaust gas recirculation is prevented.

The second pressure converter 52 is designed such that, in the non-energised state, the vacuum from the pressure medium source 41 is fed into the second control pressure chamber 25, and, in the case of full current supply, the reference pressure alone is operative in the second control pressure chamber 25. Correspondingly, the vacuum in the first control pressure chamber 25, with the second pressure converter in the non-energised state, closes the butterfly valve 11 under the influence of the return spring 26. This fulfils a safety function in that the internal combustion engine stops if either the control device or the pressure converter is without energisation. With such an arrangement, the butterfly valve 11 and exhaust gas recirculation control element 12 may be set exactly to the positions required to control the desired running, power and emission of the internal combustion engine.

The embodiment in Fig.3 is a variant of the embodiment shown in Fig.2, wherein likewise two pressure converters are provided; the first pressure converter 50, which controls the first servomotor 14, and a second pressure converter 55, which controls the second servomotor 23. As in Fig.2, the two pressure converters are supplied with pressure medium from a vacuum source 41 by way of the second throttle 40 and, in addition, are connected to the ambient air. Unlike the embodiment in Fig.2, the second pressure converter 55 operates identically to the first pressure converter 50, that is, with the pressure converter in the non-energised state, the reference pressure is fed by way of the control pressure supply line 53 to the second control pressure chamber 25 of the second servomotor 23. This has the advantage that the two pressure converters may be controlled equidirectionally. Since in order to stop the internal combustion engine shown in this development, the second pressure converter 55 must be loaded with maximum current or be pulsed with a continuous pulse, a by-pass line 56 may, for the purpose of simplification and to reduce the power requirement, be provided in parallel with the second pressure converter 55. This by-pass line 56 directly connects the control pressure chamber 25 to the pressure medium source 41 by way of a three-port, two-position solenoid valve 57 mounted in the control pressure supply line in the non-energised state and which is closed when the three-port, two-position solenoid valve is in the energised state. To stop the internal combustion engine, the three-port, two-position solenoid valve 57 is also turned off at the same time as the first pressure converter 50, so that the vacuum from the pressure source 41 acts in the closing direction on the butterfly valve 11. Alternatively, a three-port, two-position valve may be connected to the reference pressure port 37 and the pressure medium port 39, with the result that, with the three-port, two position valve in the non-energised state, the two pressure medium ports of the second pressure converter are connected to the first pressure medium source 41 only.

Fig.4 shows a variant of the embodiment according to Fig.1 having a pressure converter 36a which, when in the non-energised state feeds the reference pressure directly to the control pressure supply line 30 and closes the entrance to the pressure medium source 41. When the change-over valve 21 is in the closed position as shown, the ambient pressure is fed into the second control pressure chamber 25 by way of the second control pressure line 29. When the pressure converter 36a is in the energised state, however, and with the change-over valve 21 in the given position, the full vacuum of the pressure medium source 41 prevails in the second control pressure chamber 25. Since, in order to stop the internal combustion engine, the change-over valve 21 must be switched off in order to attain the position shown in Fig.4, and since, with the pressure converter 36a switched off, the vacuum required at the second servomotor to switch off the internal combustion engine would not be effective, a by-pass line 56 is provided in parallel with the pressure converter 36a and connects the control-pressure chamber 25 by way of a three-port, two-position solenoid valve 57 in the non-energised state mounted in the control pressure supply line directly to the pressure medium source 41 and not to the pressure converter and which is closed when the three-port, two-position solenoid valve 57 is in the energised state. When the controller is in the non-energised state, the vacuum may be fed by way of the by-pass line 56 into the second control pressure chamber 25, thus closing the butterfly valve 11.

A fifth embodiment shown in Fig.5, a variant of the embodiment shown in Fig.1, is also provided with only one pressure converter 36a, which is fed by a vacuum pump 41 as pressure medium source and which is connected on the other hand to the ambient air. When in the non-energised state, the pressure converter 36a feeds the reference pressure (= the ambient air) into the control pressure supply line 30. Varying from the embodiment in Fig.1, this control pressure line 30 leads by way of a first branch 30a into the second control pressure chamber 25, to which it is thus permanently connected, and by way of a second branch 30b into the first control pressure chamber 16. The second branch 30b is fitted with an electrically controlled and actuated change-over valve 61 (shown symbolically) which is in the form of a three-port, two-position valve and which, in the non-energised state shown, connects the servomotor end of the branch 30b to the ambient air and blocks the pressure converter end of the branch 30b. When the valve 61 is switched on, the connection between the parts of the branch 30b is restored.

In the first operating condition, the change-over valve 61 shown in this embodiment is switched on and the control pressure, which is effective in the first servomotor 14 and which is set by the pressure converter 36a, also becomes effective in the second control pressure chamber of the second servomotor 23. This means that as the cross section of the exhaust gas recirculation line is made increasingly larger by the exhaust gas recirculation control element 12, the flow cross section of intake manifold 9 becomes closed. This enables the difference in pressure at the exhaust gas recirculation control element to be stabilized and constant conditions for exhaust gas recirculation to be achieved. The stabilized pressure ratios of the exhaust gas recirculation element simplify control of the quantity of exhaust gas recirculation, and, in the event of a change in load, the supply of fresh air is effected rapidly, as the butterfly valve opens at the same time as the quantity of recirculated exhaust gas is reduced. During, acceleration, this avoids a deficit of air in the fuel-air mixture being combusted in the combustion chamber and thus avoids a discharge of soot or smoke. This device may be implemented using a pressure converter of conventional construction and a simple and economical three-port, two-position valve.

The pressure converter 36a is constructed in a first embodiment like the pressure converter 36a in Fig.4. To stop the internal combustion engine, an additional by-pass line 56, shown in the drawing as a broken line, is also provided, which connects the control pressure chamber 25 by way of an electrically actuated three-port, two-position solenoid valve 57 mounted in the control pressure supply branch 30 or 30a to the pressure medium source 41 in the non-energised state of the valve 57 and not to the pressure converter 36, 36a. When the valve 57 is switched on, the by-pass line 56 is closed and the pressure converter 36, 36a is connected to the control pressure chamber 25. As a variation to this, the pressure converter may be designed like the one in Fig.1, which, in the non-energised state, supplies the control pressure chamber 25 of the second servomotor with the pressure from the first pressure medium source 41.

The above-described embodiments are designed to be actuated by vacuum as the control pressure medium and by atmospheric pressure as the reference pressure medium. By changing the servomotors accordingly or changing the disposition of the control pressure chamber and position of the return spring or other transmission mechanism between the servomotor and throttle element, the devices described may also be operated in the same way with super-atmospheric pressure as the control pressure and atmospheric pressure as the reference pressure. In this case, the pressure chambers 18 and 27 of the servomotors, for example, would form the control pressure chambers with corresponding connection to the control pressure lines 19 and 29, while the control pressure chambers 16 and 25 would form the reference pressure chambers connected to the ambient air.

CLAIMS

1. A control system for a self-igniting internal combustion engine having an air-intake system, an exhaust gas collection system, and an exhaust gas recirculation line leading from the latter back to the intake system, said system comprising an exhaust gas recirculation control element disposed in the exhaust gas recirculation line and subjected to a restoring force in the closing direction; a first pressure medium actuated servomotor for adjusting said recirculation control element; a throttle element disposed in the intake system upstream of the juncture with the recirculation line and subjected in the opening direction to a restoring force; a second pressure medium actuated servomotor for adjusting the intake throttle element, the first and second servomotors each having a movable wall coupled respectively to the recirculation control element or the intake throttle element and separating a respective first or second control pressure chamber from a respective first or second reference pressure chamber; a control pressure converter common to the first and second servomotors or a separate control pressure converter for each servomotor, the or each control pressure converter being adopted to derive a control pressure from the pressures of a first pressure source and a second pressure source, which control pressure or pressures is or are to be applied to both of the first and second control pressure chambers of the servomotors or respectively to the first and second control pressure chambers; and a control device for producing a control signal for the or each control pressure converter in dependence upon at least one engine operating parameter.

2. A control system as claimed in claim 1, in which the first servomotor is supplied with control pressure by a first pressure converter and the second servomotor by a second pressure converter and in which the first and the second pressure converters are supplied by the same pressure sources.

3. A control system as claimed in claim 1, in which the first servomotor and the second servomotor may be supplied with control pressure by a single pressure converter, and in which an electrically controlled changeover valve is connected between the pressure converter and the servomotors, with the valve in one position connecting the first control pressure chamber of the first servomotor to the pressure converter and the second control pressure chamber of the second servomotor to the reference pressure source, and, in the other position, connecting the second control pressure chamber of the second servomotor to the pressure converter and the first control pressure chamber of the first servomotor to the reference pressure source.

4. A control system as claimed in claim 1, in which the first servomotor and the second servomotor can be supplied with control pressure by a single pressure converter, and in which an electrically controlled three-port, two-position valve is disposed between the pressure converter and the first servomotor and, in one position, connects the control pressure chamber of the first servomotor to the pressure converter and, in the other position, to the reference pressure source or the atmosphere, thus closing the connection to the pressure converter.

5. A control system as claimed in claim 3 or 4, in which the electrically controlled valve connects, in its non-energised state, the first control pressure chamber of the first servomotor to the reference pressure source.

6. A control system as claimed in any of claims 2 to 5, in which the pressure converter connected to the first servomotor is connected, in the non-energised state of such pressure converter, to the reference pressure source and feeds the reference pressure into the first control pressure chamber of the first servomotor.

7. A control system as claimed in any of claims 1 to 5, in which the pressure converter connected to the second servomotor is connected, in the non-energised state of such pressure converter, to the first pressure source and feeds its pressure to the control pressure chamber of the second servomotor.

8. A control system as claimed in claim 6, in which the pressure converter connected to the second control pressure chamber of the second servomotor has, in the non-energised state of such pressure converter, broken the connection to the first pressure source, and in which, in addition to such pressure converter, a device is provided for connecting the second control pressure chamber of the second servomotor to the first pressure source, such device having an electrically controlled (three-port, two-position) valve which, in its non-energised state, connects the pressure source to the second control pressure chamber and blocks the connection between the second control pressure chamber and the reference pressure source and which is controlled by the control device.

9. A control system as claimed in any of claims 1 to 8, in which the first pressure source is a pneumatic vacuum source.

10. A control system as claimed in any of claims 1 to 8, in which the first pressure source is a pressure medium pump adapted to be operated only when the internal combustion engine is running.

11. A control system as claimed in any of claims 1 to 10, in which the control device controls the pressure acting in the control pressure chambers of the first and the second servomotors, in such a way that, in a first operating condition (exhaust gas recirculation), the second control pressure chamber of the second servomotor is subjected to the reference pressure and the first control pressure chamber of the first servomotor is subjected to the control pressure, and that, in a second operating condition (idling, burning off of soot filter, stopping), the control pressure chamber of the first servomotor is subjected to the reference pressure and the control pressure chamber of the second servomotor is subjected to the control pressure.

12. A control system as claimed in any preceding claim, in which, in a first operating condition (exhaust gas recirculation), the control pressure fed to the first servomotor is altered in such a way that residual filling of the combustion chamber with recirculated quantities of exhaust gas is effected according to an adjustable fuel-air ratio of the media fed to the combustion chamber of the internal combustion engine.

13. A control system as claimed in any of claims 1 to 12, in which the intake cross section of the intake system is controlled in accordance with operating parameters by the throttle element which is controlled by the control device, to produce low running noise in an internal combustion engine with low load and when idling, whilst retaining a desired fuel-air ratio.

14. A control system as claimed in claim 13, in which the internal combustion engine has a soot collection device in the exhaust-gas collection system for collecting soot contained in the exhaust gas, and in which, in the second operating condition, the exhaust gas temperature may be raised by throttling the intake cross section of the intake system with the aim of burning off the collected soot, whereby the rise in exhaust gas temperature is controlled by characteristic values of the collection device or other parameters.

15. A control system as claimed in any of claims 1 to 14, in which, by switching off the control device, the second operating condition (idling, burning off soot filter, stopping) may be produced and/or the control pressure chamber of the second servomotor may be subjected to the pressure from the first pressure source.

16. A control system as claimed in any preceding claim, in which the reference pressure chambers of the servomotors are connected to the reference pressure source or sources for the control pressure converter or converters.

17. A control system as claimed in any preceding claim, in which the reference pressure chambers of the servomotors are under atmospheric pressure.

18. A control system as claimed in any preceding claim, in which the reference pressure source for the or each control pressure converter is atmospheric.

19. A control system as claimed in any preceding claim, in which the control device is responsive to the quantity of air inducted by and the quantity of fuel fed to the engine.

20. A control system for a self-igniting internal combustion engine, constructed and adapted to operate substantially as herein described with reference to and as illustrated in the accompanying drawings.

21. A method of controlling gases comprising on the one hand, air and, on the other hand, recirculated quantities of exhaust gas fed to the combustion chamber or chambers of a self- igniting internal combustion engine, in which the recirculation quantity of exhaust gas is controlled by an exhaust gas recirculation control element actuated by a controllable pressure medium, and in which, in a first operating range, and with recirculated exhaust gas, the air is fed unrestrictedly and, in a second operating range, the air fed in is also controlled by a throttle element actuated by a controllable pressure medium, and the exhaust gas recirculation is discontinued.

22. A method as claimed in claim 21, in which, in the second operating range, the quantity of air is adapted, by throttling, to the quantity of fuel to be injected, in dependence on operating parameters of the internal combustion engine, particularly in relation to low-noise running of the internal combustion engine.

23. A method as claimed in claim 22, in which throttling is controlled in dependence on exhaust gas emission conditions.

24. A method as claimed in claim 23, in which throttling is controlled to increase the exhaust gas temperature in order to burn off soot which has collected in a collection device.

25. A method as claimed in claim 22, in which the internal combustion engine may be stopped by throttling the quantity of air.

26. A method as claimed in any of claims 21 to 25, in which adjustment of the throttling element controlling the quantity of air and of the exhaust gas recirculation control element controlling the recirculated quantity of exhaust gas is effected by the control pressure produced from two initial pressures by an electrically controlled pressure converter, and in which, when the control device is switched

off, the exhaust gas recirculation line is closed by the exhaust gas recirculation control element upon which a restoring force acts, and the intake system is opened by the throttle element upon which a restoring force acts, and, when the internal combustion engine is running, is closed when actuated by one of the initial pressures.

27. A method of controlling gases substantially as herein described with reference to and as illustrated in the accompanying drawings.

Printed in the United Kingdom for
Her Majesty's Stationery Office, Dd 8818935, 1986, 4235.
Published at The Patent Office, 25 Southampton Buildings,
London, WC2A 1AY, from which copies may be obtained.