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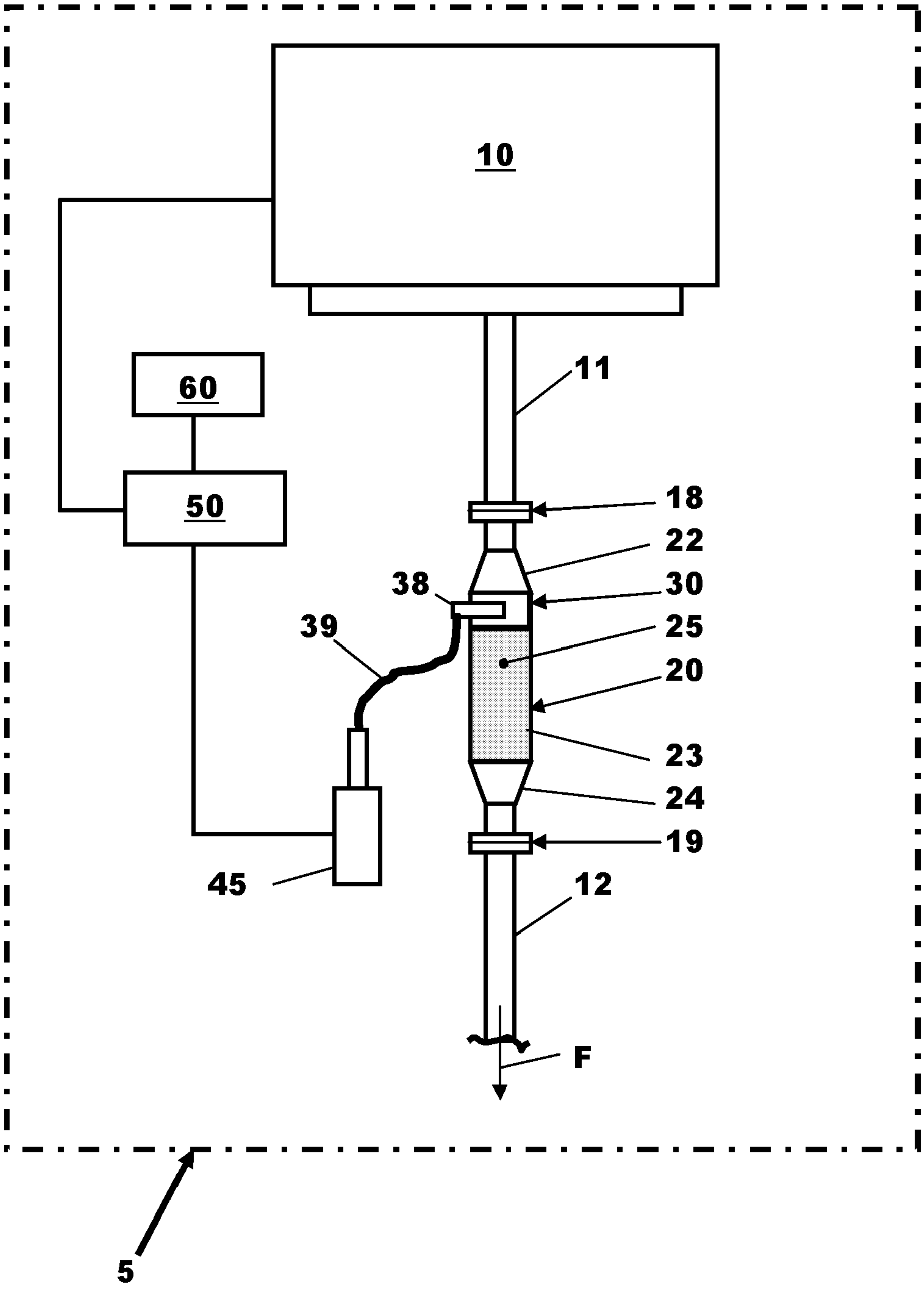
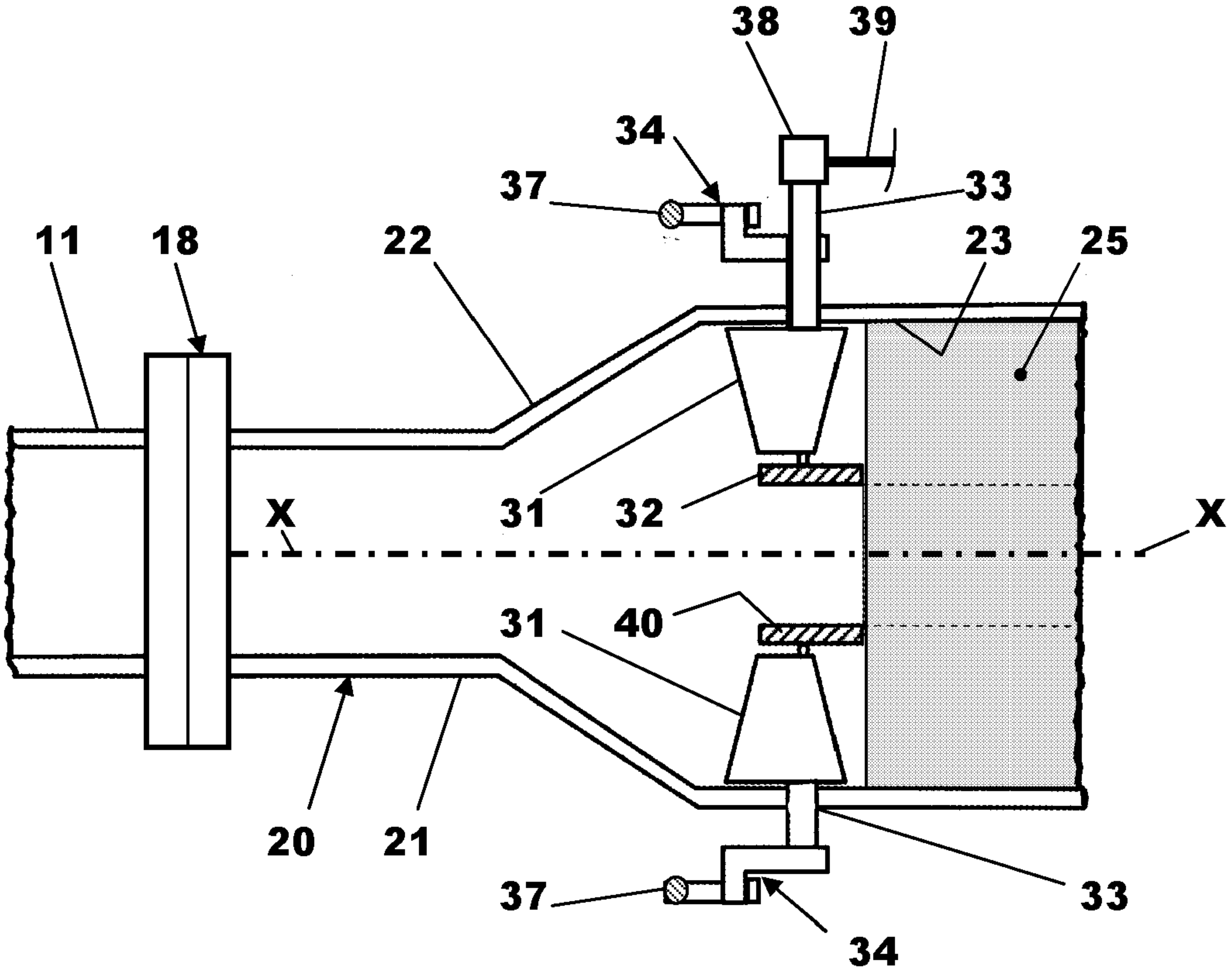


Fig.1



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X
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Fig.2

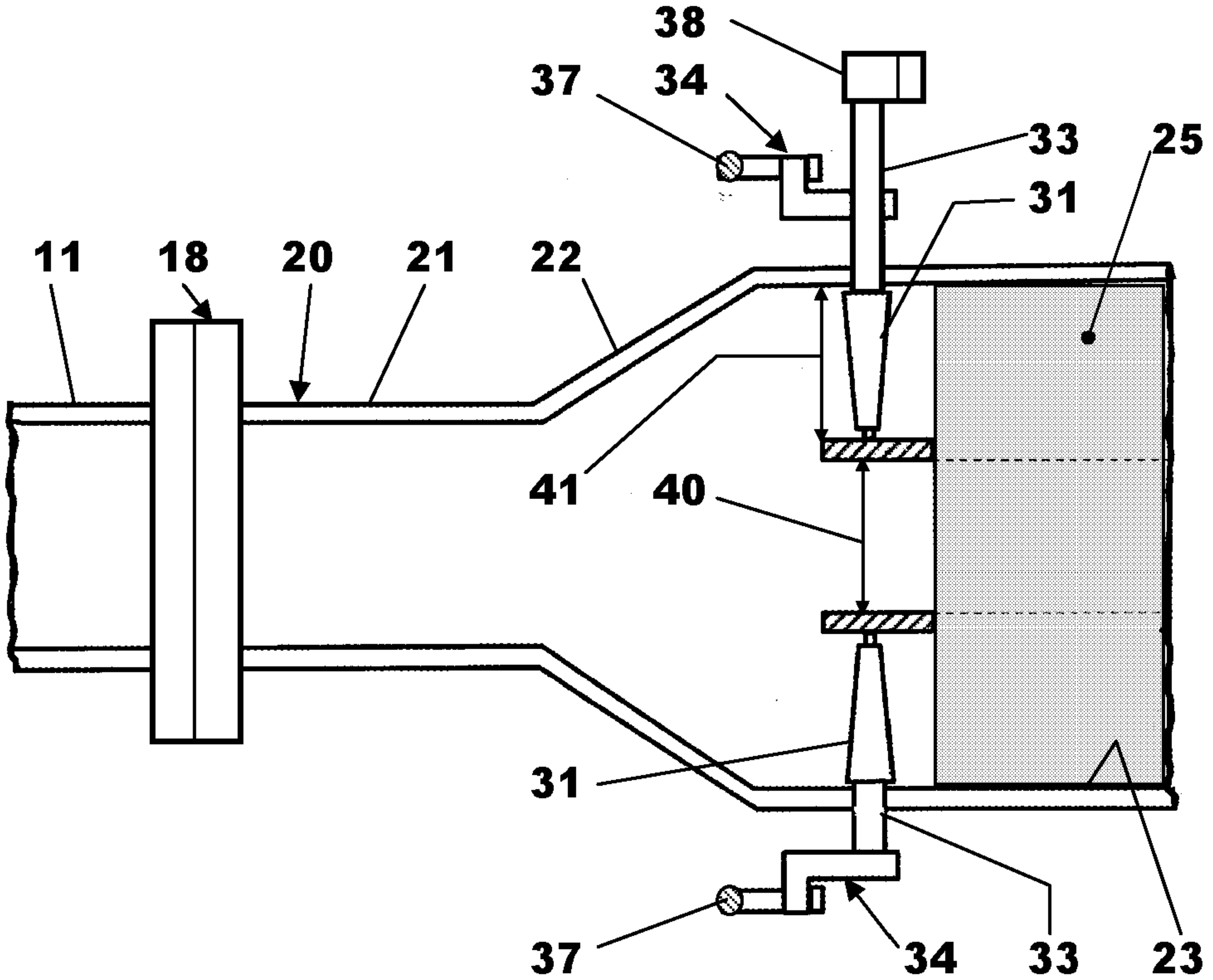

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Fig.3

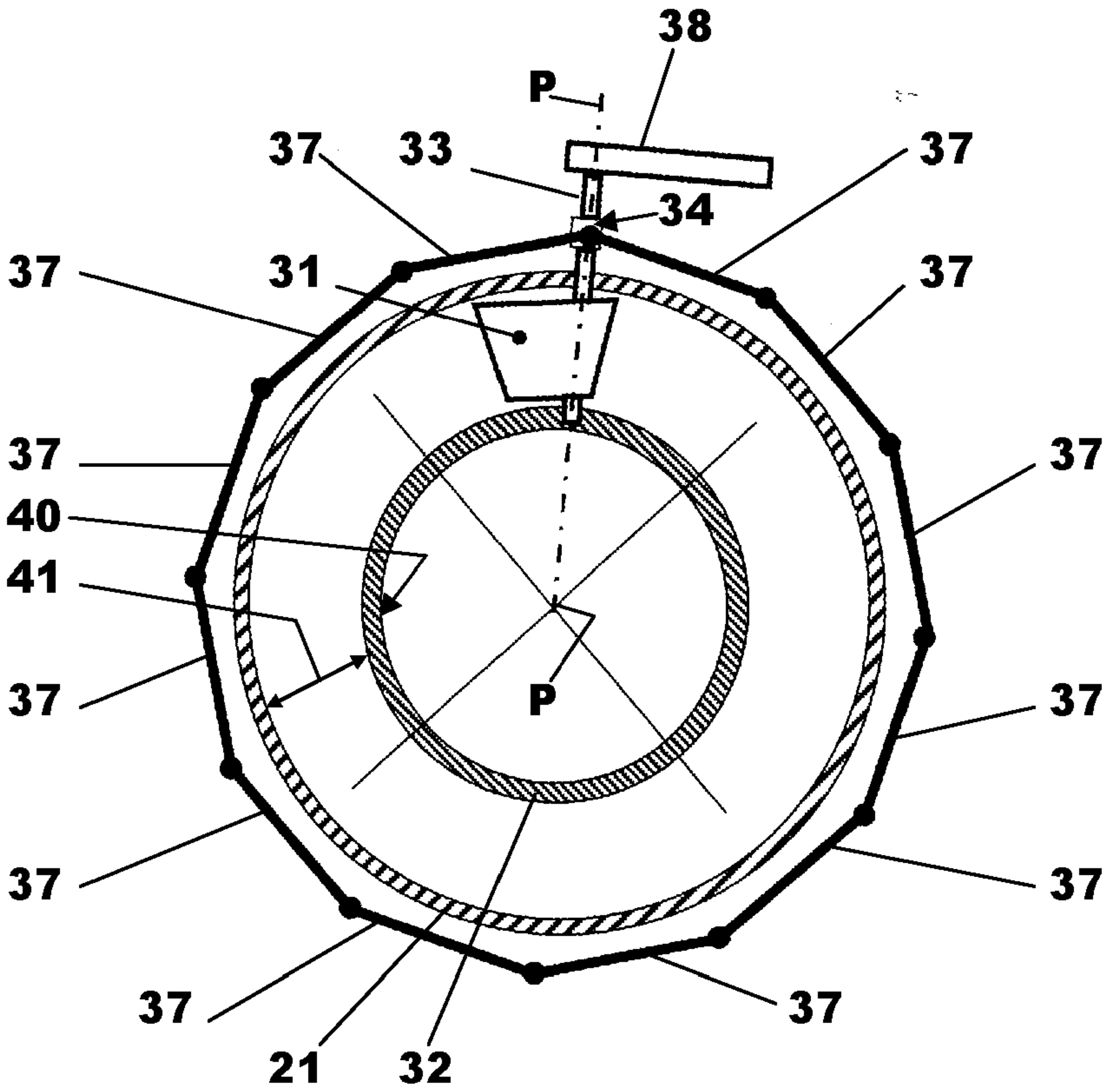
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Fig.4

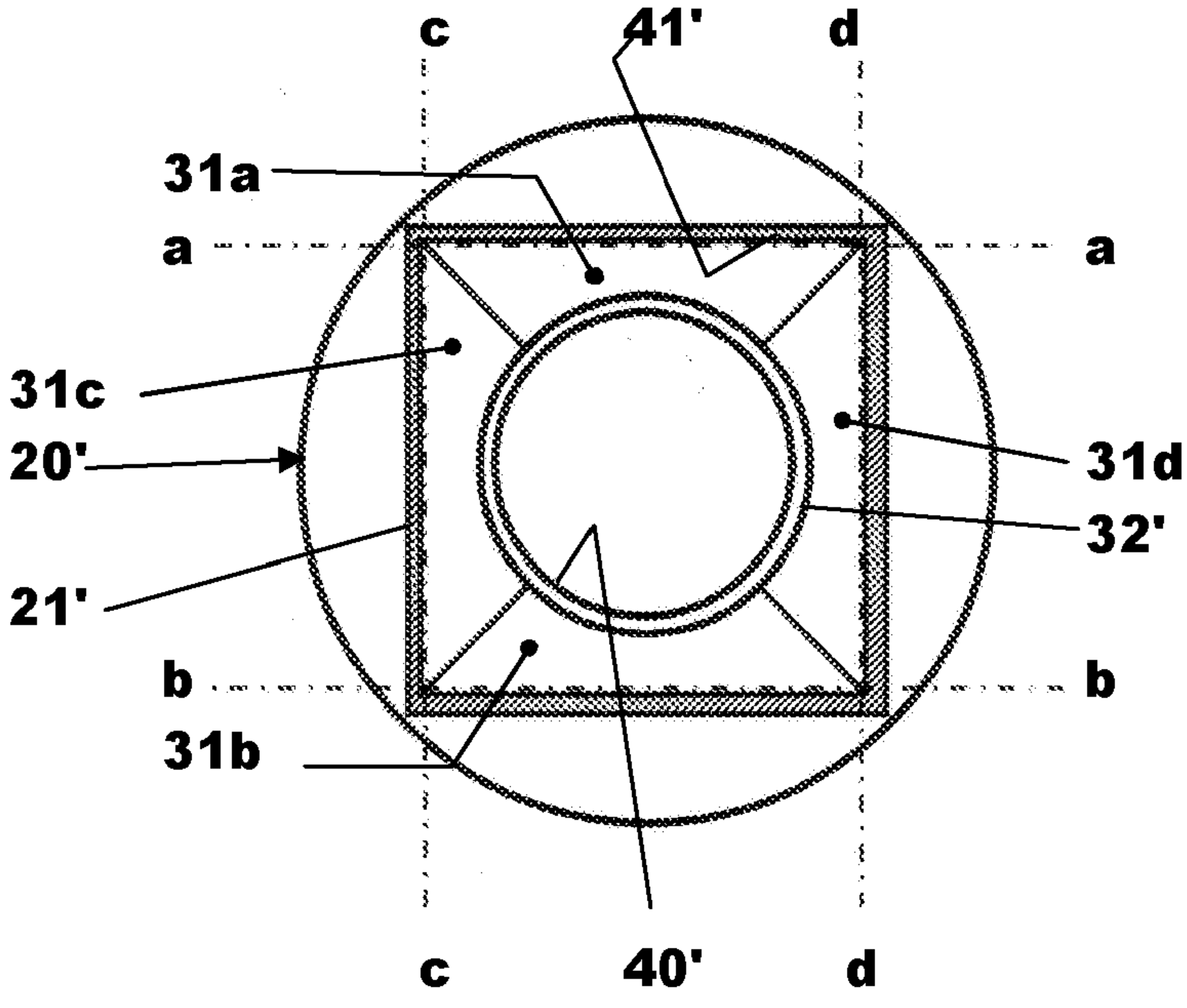
c
41'
d
31a
a
a
31c
20'
31d
32'
21'
b
b
31b
c
40'
d

Fig.6

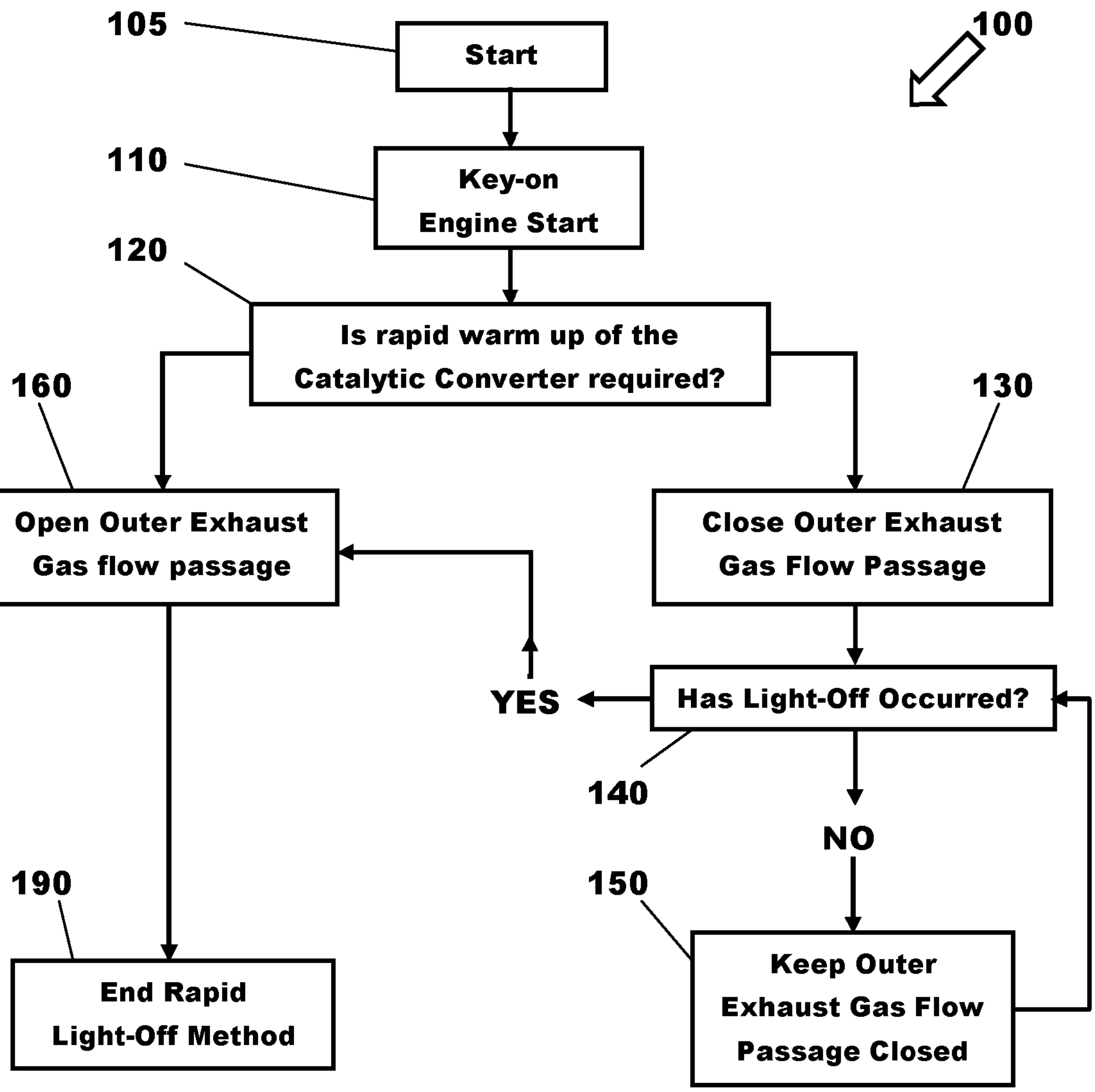
105
Start
110
Key-on
Engine Start
120
Is rapid warm up of the
Catalytic Converter required?
160
Open Outer Exhaust
Gas flow passage
130
Close Outer Exhaust
Gas Flow Passage
YES
Has Light-Off Occurred?
140
NO
190
150
End Rapid
Light-Off Method
Keep Outer
Exhaust Gas Flow
Passage Closed
100

Fig.5

Improving Warm-up of a Catalytic Aftertreatment Device

This invention relates to a motor vehicle having an internal combustion engine and in particular to a catalytic exhaust aftertreatment device of a motor vehicle having an engine supplying exhaust gas to the aftertreatment device.

It is well know that exhaust gas emissions from internal combustion engines are reduced through the use of exhaust aftertreatment devices such as catalytic converters located in the exhaust system.

The operating efficiency of a catalytic converter is temperature dependent and a catalytic converter or, to be more precise, the catalyst brick forming the active part of the catalytic converter needs to reach a minimum temperature (light-up/off temperature) before effective conversion of the exhaust gases occurs. This minimum temperature is dependent upon a number of factors but is typically is in the region of 350 to 400deg C. There is therefore a finite time during which the catalyst temperature will be below this minimum temperature following a cold engine start during a warm-up period. During this warm-up period the exhaust gas hydrocarbon emissions out of the engine are high and so it is desirable to heat the catalyst to its minimum efficient operating temperature (the light-off temperature) as quickly as possible.

In order to rapidly raise the temperature of a catalytic converter following a cold start it is known to supply more fuel to the engine which can be by way of applying an additional load to the engine by, for example, recharging batteries or other energy storage devices which will also increase the temperature of the exhaust gas flowing from the engine or by increasing the engine idle speed to an artificially high level. Another option to reduce the time required to reach the light-off temperature is to directly inject fuel just prior to or directly into the aftertreatment device itself which combusts and thereby increases the temperature within the aftertreatment device.

Although these options will result in rapid heating of the aftertreatment device, they are all inefficient operating conditions because the fuel consumption of the vehicle will be high during this mode of operation and so such approaches will result in an unacceptably high fuel penalty.

It is an object of this invention to minimise the time taken for a catalytic exhaust aftertreatment device to reach light-off during an engine warm-up period by rapid heating of the aftertreatment device while minimising any associated fuel penalty.

According to a first aspect of the invention there is provided an emission control system having an electronic controller, an electrically controllable actuator operable in response to a control output from the electronic controller and a catalytic aftertreatment device connected to an exhaust outlet from an engine, the catalytic aftertreatment device comprising a housing defining an inlet flow passage, an outlet flow passage and a chamber in which is located a catalyst and a flow control device positioned upstream from the catalyst, the flow control device comprising inner and outer exhaust gas flow passages linking the inlet flow passage to the catalyst and a flow regulating means to selectively vary the flow of exhaust gas through the outer exhaust gas flow passage wherein the electrically controllable actuator is connected to the flow regulating means to limit the flow of exhaust gas flowing through the outer exhaust gas flow passage to speed up light-off of the catalytic aftertreatment device following a cold start up of the engine.

The flow regulating means may comprise one of a number of vanes and a number of flaps rotatable from a first position in which substantially no exhaust gas can flow through the outer exhaust gas flow passage to a second position in which there is substantially no restriction to the flow of exhaust gas through the outer exhaust gas flow passage.

The outer gas flow passage may be an annular exhaust gas flow passage.

The flow regulating means may comprise a number of vanes and the vanes may be spaced circumferentially around the annular exhaust gas flow passage.

Each of the vanes may be arranged to rotate about a respective pivot axis that extends radially outwardly from a longitudinal axis of the catalytic aftertreatment device.

All of the vanes may be linked together by a linkage mechanism so as to be moveable in unison between the first and second positions.

The linkage mechanism may have an input member for connecting the linkage mechanism to a common actuator.

The electronic controller may be arranged to move the vanes to the first position when it is required to speed up light-off of the catalytic aftertreatment device and move the vanes to the second position when light-off has occurred.

The system may further comprise at least one of an exhaust gas temperature sensor and an exhaust gas emission sensor to provide an indication to the electronic controller when light-off has occurred.

The electrically controllable actuator may be connected to the input member of the linkage mechanism.

According to a second aspect of the invention there is provided a motor vehicle having an emission control system constructed in accordance with said first aspect of the invention.

According to a third aspect of the invention there is provided a method for reducing the time required for a catalytic aftertreatment device forming part of an emission control system constructed in accordance with said first aspect of the invention that is connected to receive exhaust gas from an engine to reach a light-off temperature, wherein the method comprises establishing whether an engine start-up is a cold engine start up and if the start-up is a cold engine start-up using the electrically controllable actuator to control the flow regulating means to restrict the flow of exhaust gas through the outer flow passage so as to speed up light-off of the catalytic aftertreatment device.

The invention will now be described by way of example with reference to the accompanying drawing of which:-

Fig.1 is a schematic representation of a motor vehicle according to a second aspect of the invention having an emission control system in accordance with a first aspect of the invention engine that includes a catalytic aftertreatment device;

Fig.2 is a cut-away side view of an inlet end of the catalytic aftertreatment device shown in Fig.1 showing an exhaust gas flow control device according to one embodiment of the invention in a maximum exhaust gas flow state;

Fig.3 is a view similar to Fig.2 but showing the exhaust gas flow control device in a minimum exhaust gas flow state;

Fig.4 is an end view of the catalytic converter showing part of an actuation mechanism for the flow control device and a single flap of a flow regulating means in the minimum exhaust gas flow state of Fig.3;

Fig.5 is a high level flow chart of a method for reducing the time required for a catalytic aftertreatment device to reach a light-off temperature in accordance with a third aspect of the invention; and

Fig.6 is a view similar to Fig.4 but showing an alternative embodiment of a flow control device.

With reference to Fig.1 there is shown a motor vehicle 5 having an internal combustion engine 10. The engine 10 has an upstream exhaust pipe 11 to flow exhaust gas from the engine 10 to an exhaust gas catalytic aftertreatment device which in the case of this example is in the form of a catalytic converter 20 and a downstream exhaust pipe 12 to flow exhaust gas from the catalytic converter 20 to atmosphere as indicated by the arrow ‘F’.

A flanged coupling 18 is used to connect the upstream exhaust pipe 11 to an inlet end of the catalytic converter 20 and a flanged coupling 19 is used to connect the downstream exhaust pipe 12 to an outlet end of the catalytic converter 20.

It will be appreciated that the invention is not limited to use with a catalytic converter but could also be applied to other types of catalytic aftertreatment device requiring rapid warm-up in order to achieve early effective operation.

The catalytic converter 20 has a housing 21 defining an inlet flow passage 22, an outlet flow passage 24 and a cylindrical chamber 23 in which is located a catalyst brick 25 and a flow control device 30 positioned upstream from the catalyst brick 25. As is well known in the art a catalyst brick normally takes the form of a ceramic monolith having a ceramic structure coated with catalyst material.

The flow control device 30 comprises a tube 32 defining in combination with a wall of the housing 21 defining the chamber 23 inner and outer exhaust gas flow passages 40 and 41 and a flow regulating means in the form of a number of moveable flaps or vanes 31 located in the outer exhaust gas flow passage 41. In the case of this example the outer exhaust gas flow passage 41 is an annular flow passage due to the circular shape of the chamber 23 and the tube 32 when viewed in transverse cross-section.

The vanes 31 are spaced circumferentially around the annular exhaust gas flow passage 41 and each vane 31 is arranged to be rotatable about a respective pivot axis P-P (See Fig.4) that in the case of this example extends radially outwardly from a longitudinal axis X-X (See Fig.2) of the catalytic converter 20 by respective pivot pins 33.

Fig.4 shows the view from an inlet end of the catalytic converter 20 of a single vane 31 in a flow inhibiting rotational position corresponding to the position of the vanes 31 shown in Fig.3.

The flow control device 30 forms part of an exhaust gas flow control apparatus that also includes a linkage mechanism comprising a number of link arms 34 interconnected by links 37, operated by a remote electrically controllable actuator in the form of an electrically controllable ram 45 via a cable drive 39 that is connected via an input member in the form of a lever 38 to an extended one of the pivot pins 33.

The electrically controllable ram 45 is operable in response to a control output from an electronic controller 50 to rotate the vanes 31. Because all of the vanes 31 are linked together by the link arms 34 and links 37 of the linkage mechanism the vanes 31 are all moveable in unison between a first flow controlling position in which substantially no exhaust gas can flow through the outer exhaust gas flow passage 41 (as shown in Figs.3 and 4) and a second flow controlling position in which there is substantially no restriction on the flow of exhaust gas through the outer exhaust gas flow passage 41 (as shown in Fig.2).

That is to say, the vanes 31 are rotatable in unison about their respective pivot axes P-P from the first position to the second position depending upon whether there is a need to produce rapid light-off of the catalyst brick 25 as determined by the electronic controller 50.

In the first position the vanes 31 are arranged substantially at ninety degrees to the normal direction of flow of exhaust gas through the outer exhaust gas flow passage 41 and either lie such that one edge of one vane 31 rests upon an opposite edge of an adjacent vane 31 or the vanes 31 are positioned so that there is substantially no gap between the edges of adjacent vanes 31.

In the second position the vanes 31 are arranged substantially in-line with the normal direction of flow of exhaust gas through the outer exhaust gas flow passage 41 and so have minimal effect on the flow of exhaust gas through the outer exhaust gas flow passage 41 to a front face of the catalyst brick 25. There may be a small angle of incidence between the direction of exhaust gas flow and each vane 31 in some cases but this will not significantly impede the flow of exhaust gas through the outer exhaust flow passage 41 but will induce swirl to the flow exiting the outer exhaust gas flow passage 41.

The electronic controller 50 is connected to the engine 10 and is operable to control the air supply and fuelling of the engine 10. The electronic controller 50 is further arranged to receive a number of inputs from sensors shown as reference numeral 60 in Fig.1 which are used to control the operation of the engine 10 and, in the case of this invention, also control the operation of the exhaust gas flow control apparatus.

The sensors 60 include any sensor required by the electronic controller 50 to operate the engine 10 efficiently and control the operation of the exhaust gas flow apparatus such as, for example, an engine speed sensor, an inlet air mass flow sensor, an engine coolant temperature sensor, one or more exhaust gas emission sensors and one or more exhaust gas temperature sensors.

An emission control system is comprised of the electronic controller 50, the flow control apparatus and the catalytic aftertreatment device in the form of the catalytic convertor 20.

During use the electronic controller 50 is arranged to receive a temperature input from a temperature sensor (not shown) forming one of the sensor inputs 60 that can be used to determine whether rapid warm-up of the catalytic converter 20 is required. This temperature sensor may measure the temperature of the catalytic converter 20 or may measure a temperature associated with the engine 10 such as for example a coolant temperature.

It will be appreciated that, if the engine 10 is at or close to ambient temperature, then it is likely that rapid warm-up of the catalytic converter 20 will be required but, if the engine 10 is at or close to its normal operating temperature, then it is likely that the catalytic converter 20 is also relatively hot and so rapid or enhanced warm-up of the catalytic converter 20 is not likely to be required.

For example, in the case of an engine fitted with stop-start control (such as used in micro-hybrid and hybrid motor vehicles) in which the engine 10 will be frequently stopped and started in order to save fuel, it is not desirable to unnecessarily operate the exhaust gas flow control apparatus every time the engine 10 is restarted if the catalytic converter 20 is still hot. Such unnecessary operation is disadvantageous in that it will produce increased wear of the components forming the exhaust gas flow control apparatus and will likely produce unnecessary exhaust gas flow disturbances during the transition of the vanes 31 between their respective first and second positions.

Therefore following start-up of the engine 10 the electronic controller 50 is operable to firstly determine from the temperature input received from the engine 10 or the catalytic converter 20 whether rapid warm-up of the catalytic converter 20 is required.

If rapid warm-up of the catalytic converter 20 is not required then the controller 50 is operable to use the electrically controllable ram 45 to move the vanes 31 to their respective second positions or maintain them in their respective second positions and fuel the engine 10 normally so as to achieve maximum fuel economy and minimum emissions based upon the demand placed upon it.

If rapid warm-up of the catalytic converter 20 is required then the controller 50 is operable to use the electrically controllable ram 45 to move the vanes 31 to their respective first positions and fuel the engine 10 normally so as to achieve maximum fuel economy and minimum emissions based upon the demand placed upon it.

It is preferred if the electronic controller 50 is arranged to place or maintain the vanes 31 in their respective second positions whenever the engine 10 is shut-down to reduce the risk of undesirable exhaust gas flow disturbances when the engine 10 is restarted.

Therefore, whenever rapid warm-up of the catalytic converter 20 is required, which is normally following a start-up from cold, the vanes 31 are moved to their respective first positions thereby preventing or severely restricting the flow of exhaust gas through the outer exhaust gas flow passage 41. This has the effect of forcing substantially all of the exhaust gas to flow through the inner exhaust gas flow passage 40 thereby rapidly heating the core of the catalyst brick 25 due to the increased energy density of the exhaust gas flowing through the inner exhaust gas flow passage 40. This concentrated heating has the effect of reducing the time required for the central core of the catalyst brick 25 to light-off and thereby shortens the time before the catalytic converter 20 can effectively reduce the tailpipe emissions from the motor vehicle 5 without requiring additional fuel to be supplied.

The light-off of the core of the catalyst brick 25 will, due to the reactions that occur within the catalyst brick 25 after light-off, cause heat to be generated that will spread radially outwardly thereby rapidly heating the outer parts of the catalyst brick 25.

With reference to Fig.5 there is shown a method 100 for reducing the time required for a catalytic aftertreatment device to reach a light-off temperature according to the invention. 'A rapid light-off method'

The method 100 starts at box 105 and then advances to box 110 which is a 'key-on' and engine start-up event. The method 100 then advances to box 120 where it is determined whether rapid warm-up of a catalytic aftertreatment device such as the catalytic converter 20 is required. As previously referred to, this can be determined via a direct measurement of the temperature of the catalytic converter 20 using a temperature sensor associated with the catalytic converter or be a measurement of the temperature of the engine 10 from, for example, one of an engine coolant temperature sensor, engine cylinder block temperature sensor or an engine oil temperature sensor.

If at box 120 it is determined that rapid warm-up of the catalytic converter 20 is required then the method 100 advances from box 120 to box 130 where the flow of exhaust gas to the outer peripheral region of the catalyst brick 25 of the catalytic converter 20 is regulated by preventing or severely restricting the flow of exhaust gas through the outer exhaust gas flow passage 41 so as to cause substantially all of the exhaust gas from the engine 10 to flow through the inner exhaust gas flow passage 40 thereby rapidly heating the core of the catalyst brick 25.

The method 100 then advances to step 140 where it is checked whether light-off of the catalytic converter 20 has occurred. This can be inferred from measuring the temperature of the catalytic converter 20 or be based upon a measurement of the emissions downstream from the catalytic converter 20 using a suitable emission sensor such as, for example, a NOx sensor.

If the check carried out in box 140 establishes that the catalytic converter 20 has not lit-up (the temperature is below the light-off temperature) then the method 100 advances to box 150 and the flow of exhaust gas through the catalytic converter 20 is maintained in the restricted single passage mode thereby ensuring that substantially all of the exhaust gas exiting the engine 10 flows to and heats the core of the catalyst brick 25.

The method 100 then returns to box 140 to re-check whether the catalytic converter has lit-up and, if it has not, returns to box 150 and will continue to cycle through boxes 140 and 150 until eventually the check in box 140 confirms that light-off of the catalytic converter has occurred at which point the method 100 advances from box 140 to box 160.

In box 160 the flow of exhaust gas through the catalytic converter 20 is arranged to be substantially unrestricted and so exhaust gas can flow freely through both the inner and the outer exhaust gas flow passages 40 and 41. Because the flow through the outer gas flow passage 41 has previously been restricted then this will require the opening of the flow control device 30 by moving the vanes 31 to their respective second positions.

The method 100 then advances from box 160 to box 190 where it ends.

If when checked in box 120 enhanced or rapid warm-up of the catalytic converter 20 is not required, the method 100 will advance from box 120 directly to box 160.

In box 160 the flow of exhaust gas through the catalytic converter 20 is arranged to be substantially unrestricted and so exhaust gas can flow freely through both the inner and the outer exhaust gas flow passages 40 and 41. If the flow through the outer gas flow passage 41 has previously been unrestricted then this will require no change to the operating mode of the flow control device 30 but if the flow through the outer gas flow passage 41 has previously been restricted then this will require the opening of the flow control device 30 by moving the vanes 31 to their respective second positions.

As before, from box 160 the method 100 advances from box 160 to box 190 where it ends.

It will be appreciated that if at any time there is a key-off event then the method 100 will end and will be restarted when the next key-on event occurs.

It will be appreciated that because this method operates by increasing the energy density acting on the core of the catalyst brick no significant extra fuelling of the engine is required and so the catalytic converter is lit-up rapidly without incurring any significant fuel penalty.

Although the invention has been described with respect to a specific embodiment using a number of rotatable circumferentially spaced vanes it will be appreciated that other flow controlling devices able to limit the flow through the outer flow passage such as flaps could be used and that the invention is not limited to the use of circumferentially spaced vanes.

Fig.6 shows in a diagrammatic form how the flow regulating means previously described can use four flaps 31a, 31b, 31c and 31d instead of the vanes 31 previously described. The catalytic converter 20′ is intended to be a direct replacement for the catalytic converter shown in Figs.1 to 4 and operates in a similar manner to provide rapid warm-up of the catalytic converter when required.

The flap 31a is rotatable about a pivot axis a-a, the flap 31b is rotatable about a pivot axis b-b, the flap 31c is rotatable about a pivot axis c-c and the flap 31d is rotatable about a pivot axis d-d, the actuation means for rotating the flaps 31a to 31d is not shown but would be electronically controlled in a similar manner to that previously described.

As before an inner exhaust gas flow passage 40′ is defined by a tube 32′ and an outer flow passage 41′ is defined by the combination of the tube 32′ and a wall of a housing 21′ of the catalytic converter 20′.

As before the flaps 31a to 31d are rotatable in unison from a first position as shown in Fig.6 in which the flow of exhaust gas through the outer exhaust gas flow passage 41′ is prevented so that substantially no exhaust gas can flow therethrough to a second position substantially at ninety degrees to the first position where there is substantially no restriction to the flow of exhaust gas through the outer exhaust gas flow passage 41′. As before the flow of exhaust gas through the inner exhaust gas flow passage 40′is never restricted.

Although the catalytic aftertreatment device as referred to above is a catalytic converter it will be appreciated that the invention is also applicable to the rapid warm-up other types of exhaust catalytic aftertreatment device that have to be heated to a minimum temperature quickly during a warm-up period in order to function efficiently.

Typical catalyst aftertreatment devices requiring a rapid warm-up are:

- DOC a Diesel Oxidation Catalyst;
- TWC a Three Way Catalyst;
- SCR a Selective Catalytic Reduction Catalyst;
- LNT a Lean NOx Trap;
- SC a Slip Catalyst for ammonia

Therefore in summary, current known measures to produce rapid catalyst temperature light-off have a number of disadvantages such as:

a/ Injecting more fuel will result in worse fuel economy and increased CO_2 and other emissions;

b/ Altering injection and/or spark timing will result in reduced fuel economy, increased exhaust CO_2 and emissions;

c/ The use of additional precious metal loading of the catalyst brick to improve light-off performance will result in additional cost; and

d/ the use of electrical heating for the catalyst will result in added cost.

Such disadvantages are not incurred if the invention as set out in the appended claims is used thereby reducing cost, fuel usage and increasing emission performance.

It will be appreciated by those skilled in the art that although the invention has been described by way of example with reference to one or more embodiments it is not limited to the disclosed embodiments and that one or more modifications to the disclosed embodiments or alternative embodiments could be constructed without departing from the scope of the invention as set out in the appended claims.

Claims

1. An emission control system having an electronic controller, an electrically controllable actuator operable in response to a control output from the electronic controller and a catalytic aftertreatment device connected to an exhaust outlet from an engine comprising a housing defining an inlet flow passage, an outlet flow passage and a chamber in which is located a catalyst and a flow control device positioned upstream from the catalyst, the flow control device comprising inner and outer exhaust gas flow passages linking the inlet flow passage to the catalyst and a flow regulating means to selectively vary the flow of exhaust gas through the outer exhaust gas flow passage wherein the electrically controllable actuator is connected to the flow regulating means to limit the flow of exhaust gas flowing through the outer exhaust gas flow passage to speed up light-off of the catalytic aftertreatment device following a cold start up of the engine.

2. A system as claimed in claim 1 wherein the flow regulating means comprises one of a number of vanes and a number of flaps rotatable from a first position in which substantially no exhaust gas can flow through the outer exhaust gas flow passage to a second position in which there is substantially no restriction to the flow of exhaust gas through the outer exhaust gas flow passage.

3. A system as claimed in claim 1 or in claim 2 wherein the outer gas flow passage is an annular exhaust gas flow passage.

4. A system as claimed in claim 3 wherein the flow regulating means comprises a number of vanes and the vanes are spaced circumferentially around the annular exhaust gas flow passage.

5. A system as claimed in claim 4 wherein each of the vanes is arranged to rotate about a respective pivot axis that extends radially outwardly from a longitudinal axis of the catalytic aftertreatment device.

6. A system as claimed in claim 4 or in claim 5 wherein all of the vanes are linked together by a linkage mechanism so as to be moveable in unison between the first and second positions.

7. A system as claimed in claim 6 wherein the linkage mechanism has an input member for connecting the linkage mechanism to a common actuator.

8. A system as claimed in any of claims 4 to 7 wherein the electronic controller is arranged to move the vanes to the first position when it is required to speed up light-off of the catalytic aftertreatment device and move the vanes to the second position when light-off has occurred.

9. A system as claimed in claim 8 wherein the system further comprises at least one of an exhaust gas temperature sensor and an exhaust gas emission sensor to provide an indication to the electronic controller when light-off has occurred.

10. A system as claimed in claim 7 wherein the electrically controllable actuator is connected to the input member of the linkage mechanism.

11. A motor vehicle having an emission control system as claimed in any of claims 1 to 10.

12. A method for reducing the time required for a catalytic aftertreatment device forming part of an emission control system as claimed in any of claims 1 to 10 that is

connected to receive exhaust gas from an engine to reach a light-off temperature, wherein the method comprises establishing whether an engine start-up is a cold engine start up and if the start-up is a cold engine start-up using the electrically controllable actuator to control the flow regulating means to restrict the flow of exhaust gas through the outer flow passage so as to speed up light-off of the catalytic aftertreatment device.