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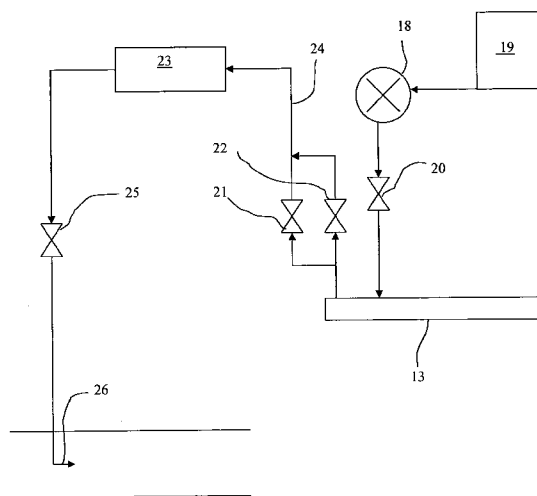
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(54) Title: EXHAUST GAS TREATMENT



(57) Abstract: An IC engine is provided with a device for generating ammonia by hydrolysis of an aqueous solution of urea and feeding it into the exhaust gas of the engine. The device includes a reaction vessel (13) arranged to receive aqueous urea from a reservoir (19) and heat the aqueous urea by heat exchange with the exhaust gas. The reaction vessel (13) has a pressure relief valve (21) set to maintain a maximum pressure in the reaction vessel (13) and a discharge valve (22) arranged to release hydrolysis product from the reaction vessel (13) when the aqueous urea has been fully hydrolysed. Both valves (21, 22) communicate with a reservoir (23) for storing hydrolysis product. A dosing valve (25) is operable to dose a volume of hydrolysis product into the exhaust gas via a nozzle (26).

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Exhaust Gas Treatment

The present invention relates to an arrangement for reducing emissions of Nitrogen oxides (NO_x) in exhaust gasses of an internal combustion (IC) engine, especially but not exclusively a diesel engine of, for example, a vehicle.

The introduction of reagents into the flow of an exhaust gas of an IC engine prior to the gas passing through a catalyst in order to effect selective catalytic reduction (SCR) of NO_x is well known.

10

The known systems principally fall into one of two categories, those which introduce gaseous ammonia into the exhaust conduit and those which introduce into the exhaust conduit a liquid reagent which decomposes into ammonia gas in the conduit.

15 The introduction of gaseous ammonia into exhaust gasses for SCR purposes has been known for a long time in association with static systems, for example the after-treatment of flue gas in power plants. Over time, the benefit of SCR has been realised in mobile solutions, initially in the shipping industry and more recently in the motor vehicle industry. Where the application is mobile, for example a motor vehicle, there are, however, safety implications in carrying a sufficiently large supply of ammonia on board to cope with requirements over an acceptable period of time. For example a rupture of the ammonia vessel, for example in a crash, could cause the release of large volumes of ammonia into the atmosphere. In addition there are additional risks of ammonia release when handling and refilling the ammonia vessel, for example at
20 roadside service stations.

25

One solution to this problem has been to inject a liquid reagent into the hot exhaust gas where it decomposes into ammonia. The liquid reagent is, at ambient temperatures, a stable medium, but it decomposes at elevated temperatures to form at least ammonia gas. It is preferably an aqueous solution of urea or related substance such as biuret or ammonium carbamate, collectively referred to, and defined, herein as "urea". While
30 this solution to the problem provides a satisfactory result, there are a number of

problems associated with it. Firstly, the liquid is injected through a nozzle as a fine spray of droplets into the fast flowing exhaust gas in which it preferably fully decomposes into at least ammonia gas prior to contacting the SCR catalyst. As this is not an instantaneous process, there needs to be a minimum separation distance

5 between the injector and the SCR catalyst to allow sufficient time to allow the full decomposition of the liquid into gas prior to it contacting the SCR catalyst. Secondly is the problem of precipitation of solids from the urea solution throughout the system and especially in the injector nozzle and catalyst. Solids formation in the nozzles tends to occur particularly where dormant urea solution has resided at a high temperature

10 under minimal pressure for a period of time in the injector nozzle. The solids may frequently block the nozzles, calling for complex control systems either to purge the nozzle, e.g. with pressurised air, or to re-circulate the urea so that it does not have the requisite time at elevated temperature for the precipitation to occur. Solidification of solids on the catalyst which occurs particularly when the liquid is dosed at low

15 temperatures below about 180 degrees C reduces the efficiency of the catalyst and increases the back pressure the catalyst creates within the exhaust system and therefore in time the catalyst will need replacing.

An alternative solution to the problem has been proposed in United States Patent

20 6,361,754 which discloses a system in which aqueous urea is hydrolysed under pressure at a high temperature so that it decomposes into at least gaseous ammonia and then introducing the gaseous ammonia into the exhaust conduit. The present invention is concerned with improvements to a system of that type.

25

According to the present invention there is provided an IC engine having a device for generating gaseous hydrolysis product comprising ammonia, formed by the hydrolysis of an aqueous solution of urea (as hereinbefore defined) at elevated temperature and pressure, and feeding it into the exhaust gas of the engine as it flows through the

30 exhaust system thereof, the device comprising:

- a) at least one reaction vessel located in, or immediately adjacent to, the exhaust manifold of the engine for containing an aqueous solution of urea and arranged such

that, in use, the urea solution within the reaction vessel becomes heated by means of heat exchange with the exhaust gas;

b) a urea solution inlet to the reaction vessel and a hydrolysis product outlet from the reaction vessel; and

5 c) a conduit arranged to convey the hydrolysis product from the reaction vessel to a point of introduction into the exhaust system downstream and remote from said manifold; and

d) valve means adapted to permit the contents of the reaction vessel, in use, to attain an elevated pressure as it becomes heated, to discharge hydrolysis product from the
10 reaction vessel, and to selectively control the feed of hydrolysis product generated in the reaction vessel into the exhaust gas via said conduit.

By placing the reaction vessel in, or immediately adjacent to, the exhaust manifold of the engine it is located in the area of hottest exhaust gas, thereby maximising heat
15 exchange to the reaction vessel. By maximising the heat exchange to the reaction vessel, the time taken to hydrolyse the urea therein is significantly reduced enabling a more responsive system as the production rate of urea can quickly be modified in response to changes in engine conditions and the related changes in NO_x concentration in the exhaust gas. By creating a more responsive system wherein the reaction time to
20 hydrolyse urea is measured in seconds rather than minutes, it may be possible, depending on the application, to feed the hydrolysis product hydrolysis product directly into the exhaust conduit from the reaction vessel. However, in some applications it may be desirable to discharge the hydrolysis product into a reservoir whence it is fed, in a controlled manner, into the exhaust gas. In addition, the
25 temperature at a position in or adjacent the exhaust manifold most closely matches the actual engine conditions thereby removing time lag from the system.

In one preferred arrangement the engine comprises a cylinder head having cylinder outlet ports therein and the reaction vessel is located within at least one of said outlet
30 ports in the exhaust gas flow such that it is heated by heat exchange with the exhaust gas as it exits the cylinders via the outlet ports. This is the point at which the exhaust gas is at its hottest and as such it is a preferred location for the reaction vessel. In one

preferred arrangement, there is a plurality of reaction vessels located, respectively, in different outlet ports.

According to another preferred arrangement the engine comprises an exhaust manifold
5 for collecting the exhaust gasses from the cylinders of the engine and the reaction
vessel is embodied in the exhaust manifold, preferably internally of it. While the
exhaust gas will cool slightly in the manifold there are advantages associated with such
an arrangement. In particular, it allows the exhaust manifold with the reaction vessel
therein to be assembled as a sub-component and then attached to the engine as a
10 complete element. This enables the engine build time to remain unchanged. In
addition it facilitates maintenance because if a system is not functioning correctly, the
manifold and reaction vessel can simply be removed as a complete item and replaced,
thereby minimising down time of the engine.

15 Preferably, when the reaction vessel is located within the exhaust gas flow, i.e. it is
exposed directly to the exhaust gas, it comprises a metal pressure vessel having a
plurality of heat exchange fins thereon to maximise, in use, heat transfer from the
exhaust gas to the urea solution within the reaction vessel.

20 In an alternative preferred arrangement, the reaction vessel is formed integrally with
the body of the exhaust manifold, more preferably the exhaust manifold is a cast
component and the reaction vessel comprises a hollow cavity cast into the exhaust
manifold. Preferably the reaction vessel comprises a metal lining inserted into the
hollow cavity, said metal lining in thermal contact with the exhaust manifold.

25 Preferably the lining body is of stainless steel. This both protects the cast metal from
the hydrolysis products and enables the reaction vessel to withstand higher pressures
than the casting alone. Preferably the cavity is tubular and the lining comprises a piece
of stainless steel tube inserted into the cavity.

30 Preferably the reaction vessel contains a hydrolysis catalyst to increase the speed of the
hydrolysis reaction. Preferably the catalyst is a zeolite or another of the hydrolysis
catalysts known in the art.

In one preferred arrangement the valve means consists of a single valve. Preferably the single valve is an fully on/off valve and the reaction vessel is operated in a batch production mode whereby aqueous urea is pumped, from a pump into the reaction chamber, is heated therein for a period of time, during which the pressure becomes elevated, sufficient for the urea to hydrolyse and the valve is selectively opened to allow the hydrolysis product to be expelled therefrom by means of the pressure which has built up within the reaction vessel. Alternatively the valve may be a pressure relief valve and the reaction vessel is partially filled with urea such that the pressure relief valve is above the level of the liquid and as the urea hydrolyses the hydrolysis products are released in gaseous form through the pressure relief valve in a continual process.

In a preferred arrangement a conduit leads from the valve to the point of introduction of hydrolysis product into the exhaust gas. Preferably at least a section of the conduit is heated by heat exchange with the hot exhaust gasses, and any liquid phase hydrolysis product exiting the reaction vessel is converted to gaseous phase hydrolysis product in said conduit.

Alternatively the valve means may comprise two valves, a first one adapted to permit the contents of the reaction vessel to attain an elevated pressure and to discharge hydrolysis product from the reaction vessel, and a second one for selectively controlling the feed of hydrolysis product into the exhaust gas, there being a conduit between them preferably comprising a reservoir which acts as a buffer between the output rate of hydrolysis produce from the reaction vessel and the input rate of hydrolysis product into the exhaust such that input of hydrolysis product into the exhaust is controlled independently of output from the reactor vessel. In a preferred arrangement the first valve is an on/off valve and the reaction vessel is operated in a batch process as described above. In this case the periodic discharge from the reaction vessel may not exactly meet the requirements of addition of hydrolysis product to the exhaust gas and the conduit acts as a buffer to temporarily store the hydrolysis product before it is introduced into the exhaust gas via the second valve that selectively controls the feed of hydrolysis product. Alternatively the valve to permit the contents

of the reaction vessel, in use, to attain an elevated pressure as it becomes heated, and to discharge hydrolysis product from the reaction vessel, may be a pressure relief valve and operate as described above in relation to the system only having one valve.

- 5 Preferably the conduit is at least partially heated by heat exchange with the hot exhaust gasses such that any liquid phase hydrolysis product discharged from the reaction vessel is converted to gaseous phase hydrolysis product within the conduit prior to passing through the second valve.
- 10 In another preferred arrangement, where the valve in the outlet of the reaction vessel is an on/off valve, there is provided a further valve in parallel with the valve in the outlet from the reaction vessel. Preferably the further valve is a pressure relief valve and both valves control the discharge of hydrolysis product from the reaction vessel. In use a volume of urea is pumped into the chamber to partially fill it and the on/off valve is
- 15 closed. As the urea becomes heated the gas pressure above the liquid level increases. Once the pressure reaches the set value of the pressure relief valve excess gas will vent out of the further, e.g. pressure relief, valve ensuring that a maximum required pressure within the reaction vessel is not exceeded. Once the urea has been in the reaction vessel for sufficient time that it has substantially all hydrolysed then the on/off
- 20 valve is opened and the contents of the reaction vessel exits via the on/off valve. Preferably the on/off valve is placed below the liquid level within the reaction vessel such that its contents are expelled therefrom by the head pressure above it.

- In a preferred arrangement there is a plurality of reaction vessels and the frequency at
- 25 which they are discharged, and/or the volume of urea supplied to them, and therefore the volume of hydrolysis product discharged from them, is increased in relation to the amount of NO_x in the exhaust gas.

- Preferably the IC engine has a turbocharger downstream of the exhaust manifold and
- 30 the point of introduction of the hydrolysis product into the exhaust gas is downstream of the turbocharger. This is highly desirable as it is possible that during normal operation small particles of water may escape into the exhaust gas with the hydrolysis

product or that if the device is run outside its normal operational parameters, for example in a system failure, that solid salts may form in the hydrolysis product. The turbocharger is a very fast moving turbine and it is detrimental to its performance and life if particulate material is passed through it, especially in its hot operating state.

5

It is preferable that the exhaust system of the IC engine further comprises an oxidation catalyst to convert a proportion of the NO contained within the exhaust gas to NO₂, and the point of introduction of hydrolysis product into the exhaust gas is downstream of the oxidation catalyst. If a substantially equal balance of NO and NO₂ can be achieved
10 in the exhaust gas then the urea needed is minimised and performance requirements of the reactor vessel are reduced.

The present invention also provides a exhaust manifold for an IC engine, said manifold
15 including a urea hydrolysis reaction vessel for containing, in use, an aqueous urea solution, the reaction vessel having a urea solution inlet and a hydrolysis product outlet.

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

Figure 1 shows a perspective view of a typical IC engine;

Figure 2 shows a perspective view of the engine of Figure 1 with the exhaust manifold
25 omitted;

Figure 3 shows a perspective view of an engine showing a number of reaction vessels arranged in the port outlets;

30 Figure 4 shows an exhaust manifold according to the present invention;

Figure 5 is an enlarged view of a portion of Figure 4;

Figure 6 shows a reaction vessel suitable for placement in the outlet ports;

Figure 7 is a schematic diagram of system using a reaction vessel shown in Figure 6;

5

Figure 8 is a perspective view of an exhaust manifold according to the present invention;

10 Figures 9 and 10 are section views of an exhaust manifold according to the present invention;

Figure 11 is a perspective view of an alternative exhaust manifold according to the present invention;

15 Figures 12 and 13 are section views of an exhaust manifold shown in Figure 11;

Referring to Figure 1, and Figure 2 a turbocharged internal combustion engine 1 is shown such as may be found on a truck or small commercial vehicle. Such engines are well known in the art and comprise a number of cylinders in which combustion occurs, the combustion drives pistons within the cylinders which rotate a camshaft from which power is transmitted to its final use - in the case of a vehicle the power is transmitted to the wheels. The main part of the engine typically comprises a number of parts which are bolted together, one of these, the cylinder head 2, encloses one end of the cylinders. The cylinder head 2 has a plurality of cylinder outlet ports 3a, b, c, d, e & f, through which the exhaust gasses exiting the cylinders, post combustion, pass. The hot exhaust gasses then pass into and through an exhaust manifold where the exhaust gas flows from the individual cylinders join together. The exhaust gasses exit a manifold 4 and pass into a turbocharger 5.

30

Referring to Figure 3 the engine 1 of Figures 1 and 2 is shown with the manifold 4 omitted for clarity. A plurality of reaction vessels 6a, b, c, d, e, f are shown, each with

an associated feed pipe 7a, b, c, d, e, f for feeding aqueous urea solution from a control block 8 into the reaction vessels. The control block 8 is shown located on the engine but it may be located anywhere conveniently in the vicinity of the engine. The control block 8 is operated to feed a small amount of aqueous urea into the reaction vessels 6 via their associated feed pipes 7. The reaction vessels 6 and therefore the urea within them are heated by the flow of hot exhaust gasses past the reaction vessels 6. In the reaction vessels 6 as the urea becomes heated it starts to decompose and releases some gas causing the pressure within the reaction vessels 6 to become elevated. The elevated pressure increases the boiling point of the aqueous urea allowing its temperature to continue to increase and thereby reduces the reaction time necessary for the urea to fully hydrolyse into a hydrolysis product containing ammonia. A conduit 9 with a valve 10 therein leaves each reaction vessel 6 to take the ammonia containing hydrolysis product therefrom. Preferably valve 10 is an on/off solenoid valve and the conduits 9 lead to a buffer vessel 11 that temporarily stores the hydrolysis product prior to it being introduced into the exhaust gas downstream of the turbocharger. Alternatively the hydrolysis product may be released directly into the exhaust either periodically via an on/off solenoid valve, or continuously via a pressure relief valve, downstream of the turbocharger. The hydrolysis gas and the exhaust gas then flow together through an SCR catalyst wherein the ammonia in the hydrolysis gas reacts with the NOx in the exhaust gas substantially converting it to nitrogen and water. When the hydrolysis gas is periodically released directly from the reaction vessel into the exhaust without the presence of a buffer, it is hard to stoichiometrically balance the input of hydrolysis gas into the exhaust gas to the amount required to remove the NOx therein in real time. This is overcome by using the SCR catalyst which is capable of adsorbing an amount of ammonia on its surface, as a temporary buffer. When the hydrolysis gas is introduced to the exhaust in small batches, as each batch passes through the SCR catalyst, the excess ammonia, above that which is used to reduce the NOx in the exhaust gas, will be adsorbed on the surface of the SCR catalyst. During the time intervals between introductions of the hydrolysis gas the ammonia adsorbed on the catalyst will react with the NOx still flowing through the catalyst thereby reducing it to nitrogen and water enabling substantially constant reduction of NOx from the exhaust gas.

Referring to Figures 4 to 6 an exhaust manifold 12 is shown that is adapted to hold a plurality of reaction vessels 13 such that they project past the flanges 14, which attach the exhaust manifold 12 to the engine, and into the outlet ports of the engine. Two
5 ports 15, 16, one for the input of aqueous urea and one for the outlet of hydrolysis product, pass from the reaction vessel 13 through the manifold 12 for connection to respective conduits (not shown). The reaction vessel 13 has a plurality of fins 17 attached to its outer surface to enhance heat transfer from the hot exhaust gasses passing over the outer surface of the reaction vessel 13. In use a pump 18 (Figure 7)
10 pumps aqueous urea from a reservoir 19 into the reaction vessel 13 via valve 20. The pump 18 and valve 20 are operated to introduce a small amount of aqueous urea, about 10ml, into the reaction vessel 13. In the reaction vessel 13 the urea becomes heated and starts to decompose. As it decomposes some of the decomposition products become gaseous causing the pressure and therefore, with the continuing input of heat,
15 the temperature to rise. Primarily the decomposition products are carbon dioxide, ammonia and water. Due to the partial pressures of the gasses, and especially that of carbon dioxide, the pressure will quickly rise. If the pressure is allowed to rise too high, around 150bar, a different hydrolysis product is formed, namely ammonium carbamate. At this high pressure the reaction is reversible and as such it is hard to
20 fully decompose the aqueous urea. This is undesirable as, if urea is allowed to leave the reaction vessel and enter a low pressure, then, at the pressures within the system, solid deposits will quickly form. Therefore it is advantageous to maintain the pressure below this pressure. This is achieved by having two outlet valves 21, 22 one of which
25 21 is a pressure relief valve set to maintain a maximum pressure of around 140bar within the reaction vessel 13. Above this temperature any excess pressure will vent through the valve and into a reservoir 23. The second valve 22, a discharge valve, is located in parallel with the pressure relief valve 21 and once the aqueous urea has been held in the reactor sufficiently long enough for it to fully hydrolyse this valve 22 is opened and the pressure within the reaction vessel 13 will expel its contents
30 therethrough. A conduit 24 connects the valves and the reservoir 23. Downstream of the reservoir 23 is a dosing valve 25 (Figure 7) which operates to dose a volume of the hydrolysis product into the exhaust gas of an IC engine via a nozzle 26.

Referring to Figures 8, 9 and 10 an exhaust manifold 27 is shown for collecting the exhaust flows from exhaust outlet ports of an engine via inlets 28 and combining the flows and ducting them out of the manifold outlet 29 towards a turbocharger. The manifold 27 is manufactured of a cast metal has two reaction vessels 30 cast into it. Each reaction vessel has an inlet 31 at its lower end and an outlet 32 at its upper end. The reaction vessels operate as described in relation to Figures 4 to 7. In both embodiments shown the reaction vessels are operated out of phase with one another so as to provide a substantially continuous flow of hydrolysis product to the exhaust.

10

Referring to Figure 11 to 13 an exhaust manifold 33 is shown for collecting the exhaust flows from exhaust outlet ports of an engine via inlets 34 and combining the flows and ducting them out of the manifold outlet 35 towards a turbocharger. The manifold 33 is manufactured of a cast metal and has two reaction vessels 36 cast into it. Each reaction vessel is lined with a stainless steel liner 36a to extend its life. Each reaction vessel has an inlet 37 at its lower end and an outlet 38 at its upper end. The reaction vessels operate as described in relation to Figures 4 to 7. When the hydrolysis product exits the reactor via the outlet 38 it enters a valve unit 39 which contains the pressure relief valve and the discharge valve and, downstream of the valve unit 39, the conduit 40 through which the hydrolysis product flows towards its point of use passes back into the manifold 33. This is a low pressure conduit and due to the heat of the manifold 33, liquid hydrolysis product discharged from the reaction vessel 36 will evaporate in the hot part 41 of the conduit within the manifold thereby ensuring that the hydrolysis product is fully gaseous before it passes into the exhaust gas. After passing through the hot section 41 the conduit 40 continues towards its point of introduction to the exhaust. Prior to entering the exhaust the hydrolysis product may be temporarily stored in a reservoir and its introduction to the exhaust is controlled by a further control valve. Alternatively the conduit 40 may lead directly into the exhaust gas at a point downstream of the turbo. The valve unit 39 may be operated to control the release of the hydrolysis product into the exhaust or a second valve (not shown) may be placed downstream to control the introduction of the hydrolysis product into the exhaust.

25
30

Claims

- 1 An IC engine including a device for generating gaseous hydrolysis product
comprising ammonia, formed by the hydrolysis of an aqueous solution of urea at
5 elevated temperature and pressure, and feeding it into the exhaust gas of the engine as
it flows through the exhaust system of the engine, the device comprising:
- a) at least one reaction vessel located in, or immediately adjacent to, the exhaust
manifold of the engine for containing an aqueous solution of urea and arranged such
that, in use, the urea solution within the reaction vessel become heated by means of
10 heat exchange with the exhaust gas;
 - b) a urea solution inlet to the reaction vessel and a hydrolysis product outlet from the
reaction vessel;
 - c) a conduit arranged to convey the hydrolysis product from the reaction vessel to a
point of introduction into the exhaust system downstream and remote from said
15 manifold; and
 - d) valve means adapted to permit the contents of the reaction vessel, in use, to attain an
elevated pressure as it becomes heated, to discharge hydrolysis product from the
reaction vessel, and to selectively control the feed of hydrolysis product generated in
the reaction vessel into the exhaust gas via said conduit.
20
- 2 An IC engine according to Claim 1 wherein the engine comprises a cylinder
head having cylinder outlet ports therein and the reaction vessel is located within an
outlet port such that it is heated by heat exchange with the exhaust gas as it exits the
cylinders via the outlet ports.
25
- 3 An IC engine according to Claim 2 wherein there are a plurality of reaction
vessels, each located in a respective outlet port.
- 4 An IC engine according to Claim 1 wherein at least one reaction vessel is
30 located in the exhaust gas flow passageway of the exhaust manifold of the engine.

5 An IC engine according to Claim 1 wherein the reaction vessel is embodied in
a wall of the exhaust manifold.

6 An IC engine according to any one of claims 1 to 5 wherein the reaction vessel
5 comprises a metal pressure vessel having a plurality of heat exchange fins thereon to
maximise, in use, heat transfer from the exhaust gas to the urea solution within the
reaction vessel.

7 An IC engine according to Claim 1 the reaction vessel comprises a hollow
10 cavity cast or machined into the exhaust manifold.

8 An IC engine according to Claim 7 wherein the reaction vessel comprises a
metal body inserted into the hollow cavity, said metal body being in thermal contact
with the exhaust manifold.

15

9 An IC engine according to Claim 8 wherein the metal body is stainless steel.

10 An IC engine according to Claim 9 wherein the cavity is substantially tubular
and has a lining comprising a piece of stainless steel tube inserted into the cavity.

20

11 An IC engine according to any of the preceding claims wherein the valve
means consists of a single valve in the outlet of the reaction vessel.

12 An IC engine according to Claim 11 wherein the valve is a pressure relief valve
25

13 An IC engine according to Claim 11 wherein the valve is a fully on/off valve.

14 An IC engine according to Claim 12 wherein the valve is operable on a timed
basis.

30

15 An IC engine according to any one of claims 1 to 10 wherein the valve means
comprises a first valve adapted to permit the contents of the reaction vessel to attain an

elevated pressure and to discharge hydrolysis product from the reaction vessel, and a second valve for selectively controlling the feed of hydrolysis product generated in the reaction vessel into the exhaust gas, the first and second valves being interconnected by a conduit.

5

16 An IC engine according to Claim 15 wherein the conduit comprises a section heated by heat exchange with the hot exhaust gasses, and in which any liquid phase hydrolysis product is converted to gaseous phase hydrolysis product.

10 17 An IC engine according to Claim 16 wherein the conduit further comprises a reservoir between the output of the reaction vessel and the input of hydrolysis product into the exhaust such that input of hydrolysis product into the exhaust is controlled independently of output from the reactor vessel.

15 18 An IC engine according to Claim 16 or Claim 17 wherein the first valve is an on/off valve.

19 An IC engine according to Claim 16 or Claim 17 wherein the second is a pressure relief valve.

20

20 An IC engine according to any one of claims 16 to claim 19 wherein the conduit is at least partially heated by heat exchange with the hot exhaust gasses, and in which any liquid phase hydrolysis product is converted to gaseous phase hydrolysis product.

25 21 An IC engine according to Claim 16 and wherein the first valve in the outlet of the reaction vessel is an on off valve and there is provided a further valve, in parallel with the first valve, in the outlet from the reaction vessel.

22 An IC engine according to Claim 21 wherein the further valve is a pressure
30 relief valve

- 23 An IC engine according to Claim 22 wherein, in use, once the pressure reaches the set value of the pressure relief valve, any excess gas produced during the hydrolysis reaction will vent out of the pressure relief valve ensuring that the set pressure is not exceeded in the reaction vessel.
- 5
- 24 An IC engine according to any one of claims 21 to 23 wherein, once the urea in the reaction vessel has substantially hydrolysed then the on/off valve is opened and the contents of the reaction vessel exits via the on/off valve.
- 10 25 An IC engine according to any one of Claims 21 to 24 wherein the on/off valve is placed below the liquid level within the reaction vessel such that any liquid phase reaction medium it is expelled therefrom by the head pressure above it.
- 15 26 An IC engine according to any of the preceding claims wherein the reaction vessel contains a hydrolysis catalyst.
- 27 An IC engine according to any of the preceding claims wherein the IC engine has a turbocharger downstream of the exhaust manifold and said point of introduction of hydrolysis product into the exhaust gas is downstream of the turbocharger.
- 20 28 An IC engine according to any of the preceding claims wherein the exhaust system comprises an oxidation catalyst to convert a proportion of the NO contained within the exhaust gas to NO₂, and the point of introduction of hydrolysis product into the exhaust gas is downstream of the oxidation catalyst.
- 25 29 An exhaust manifold for an IC engine, said manifold including a urea hydrolysis reaction vessel for containing, in use, an aqueous urea solution, the reactor vessel having a urea solution inlet and a hydrolysis product outlet.
- 30 30 An exhaust manifold according to Claim 29 incorporating one or more features set out in claim 4 to 10.

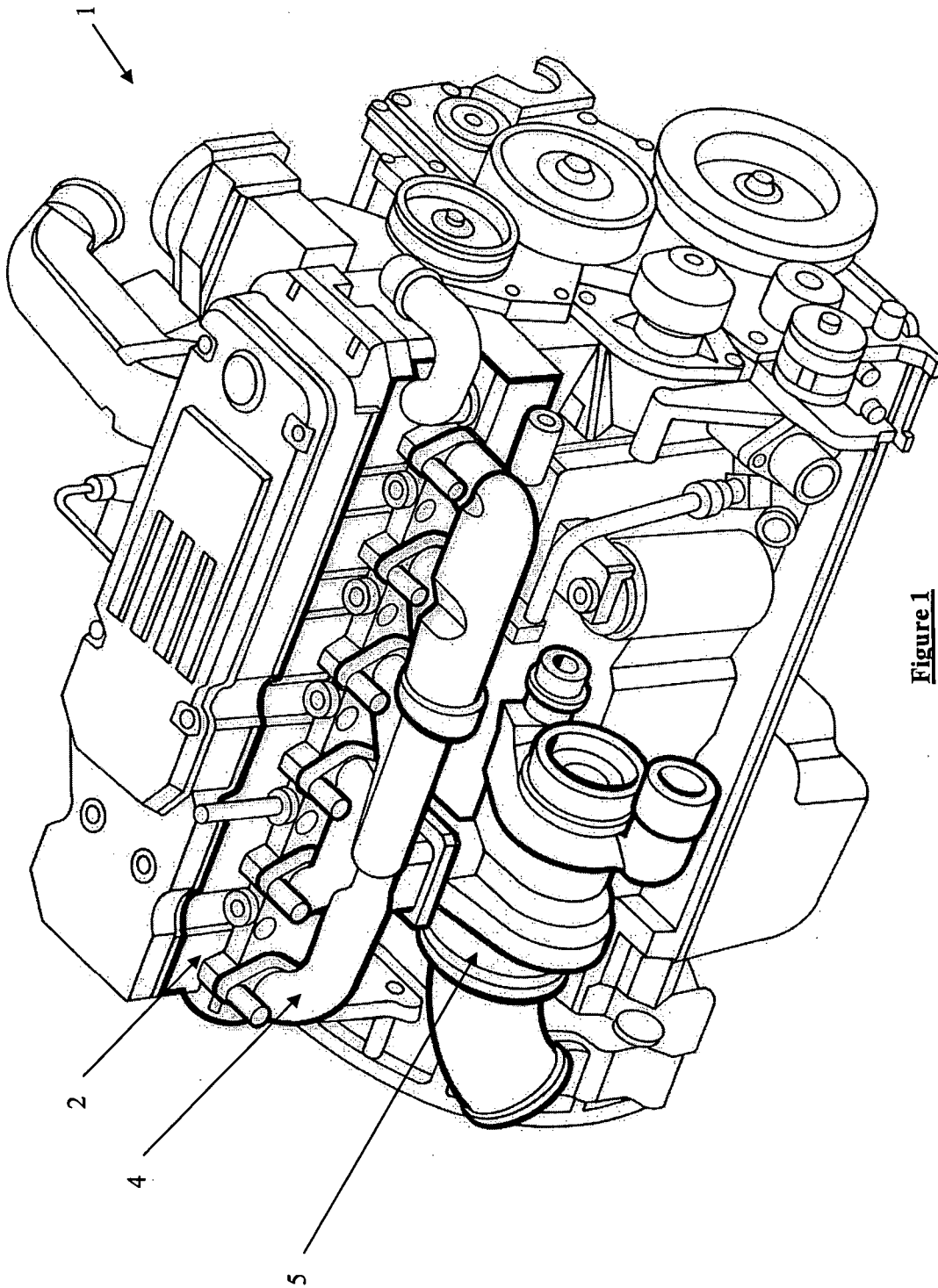


Figure 1

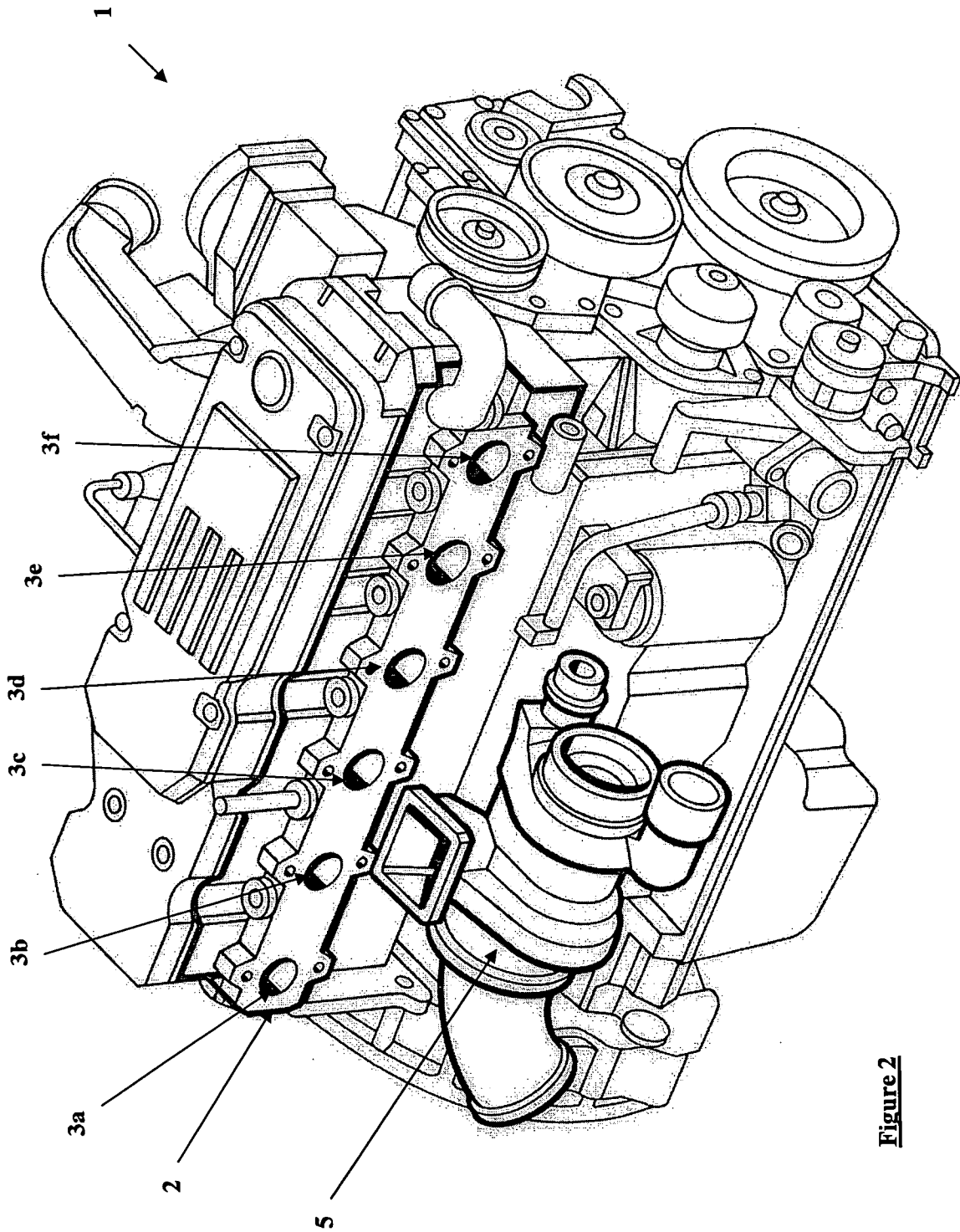


Figure 2

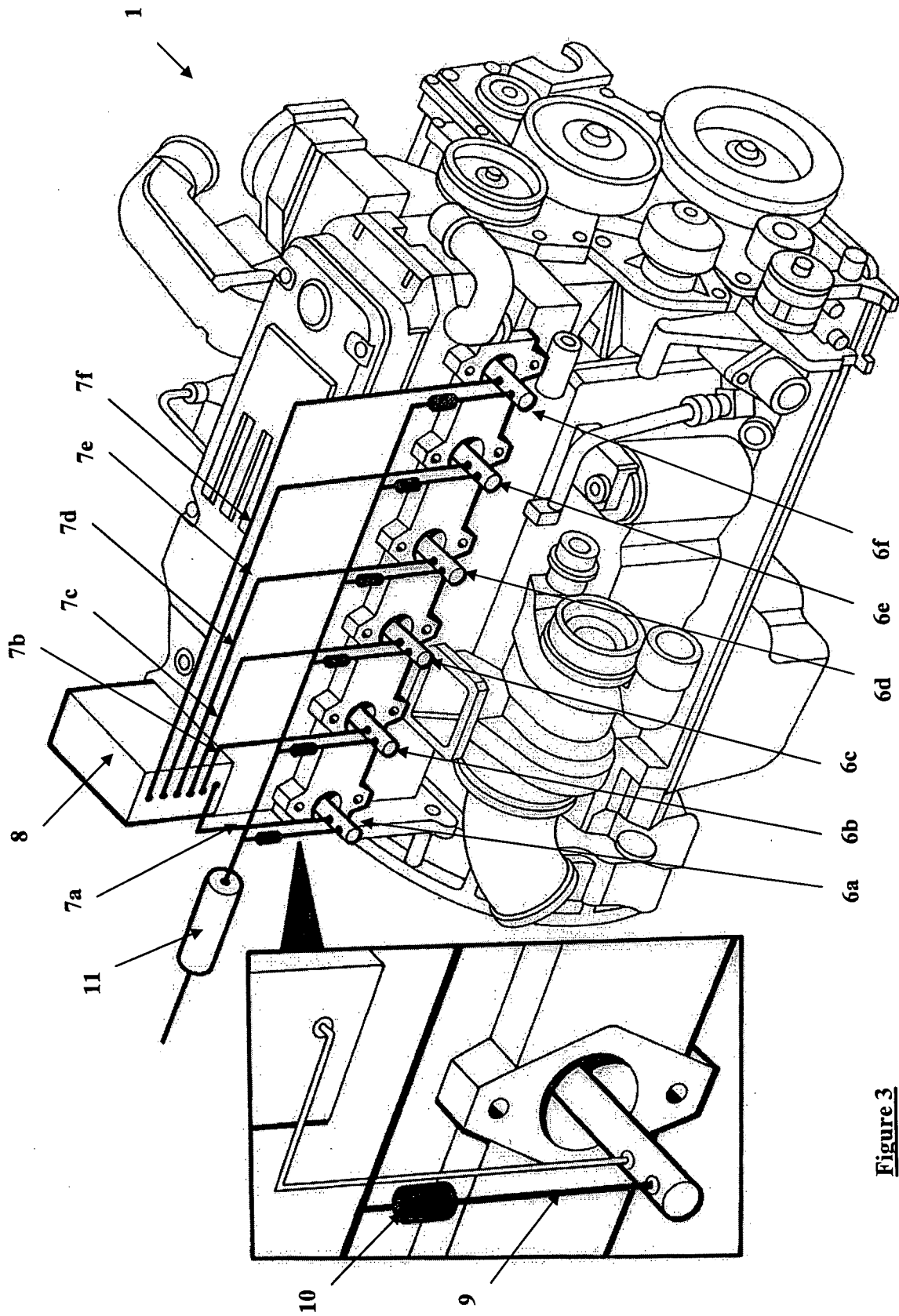
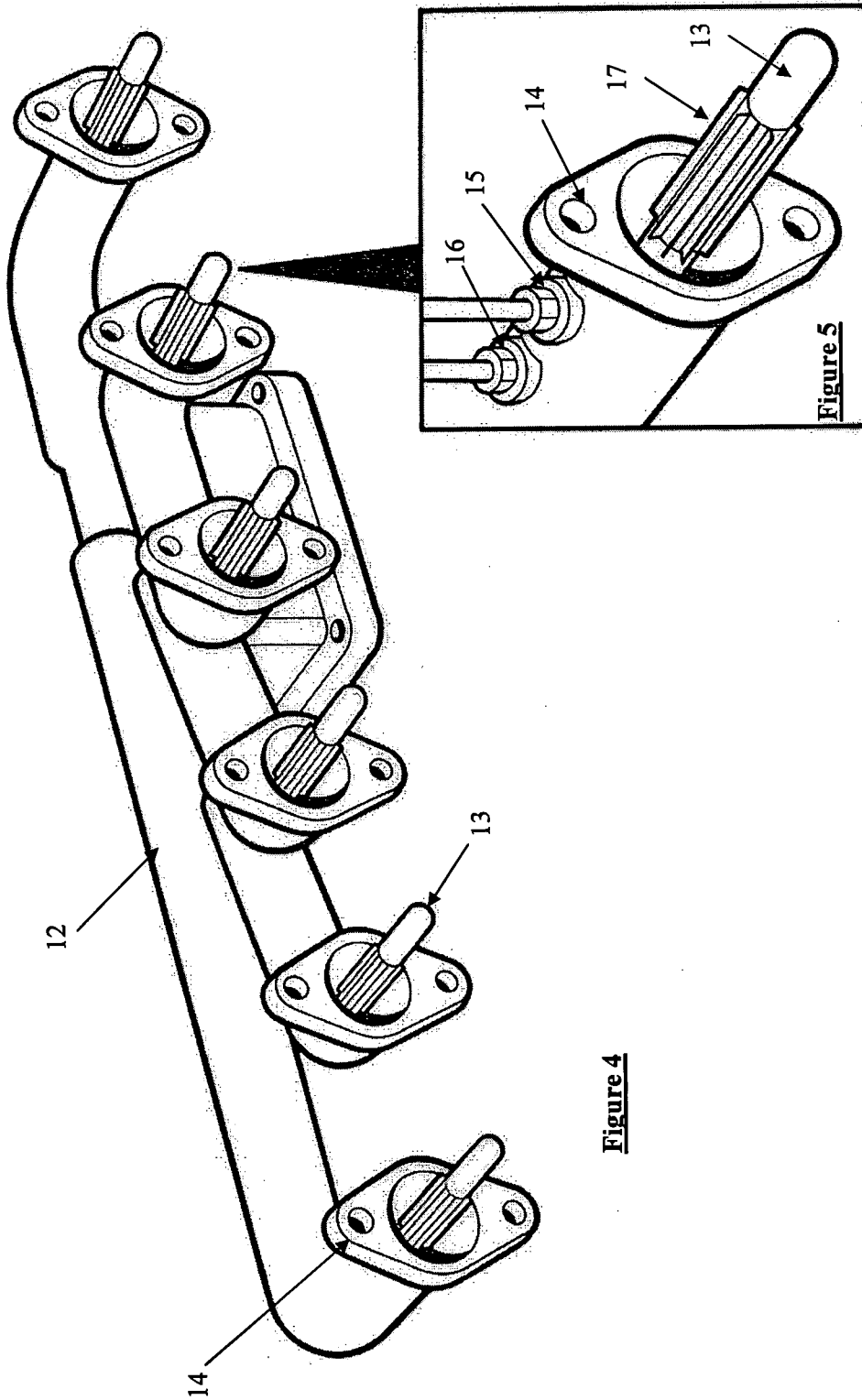


Figure 3



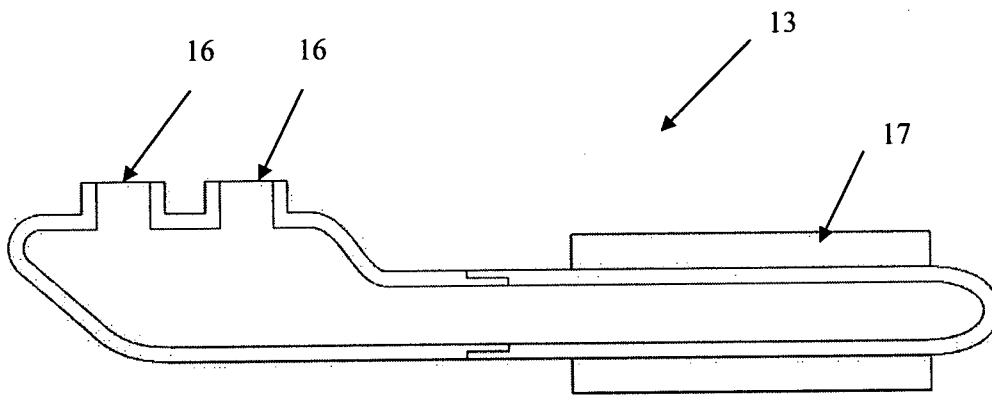


Figure 6

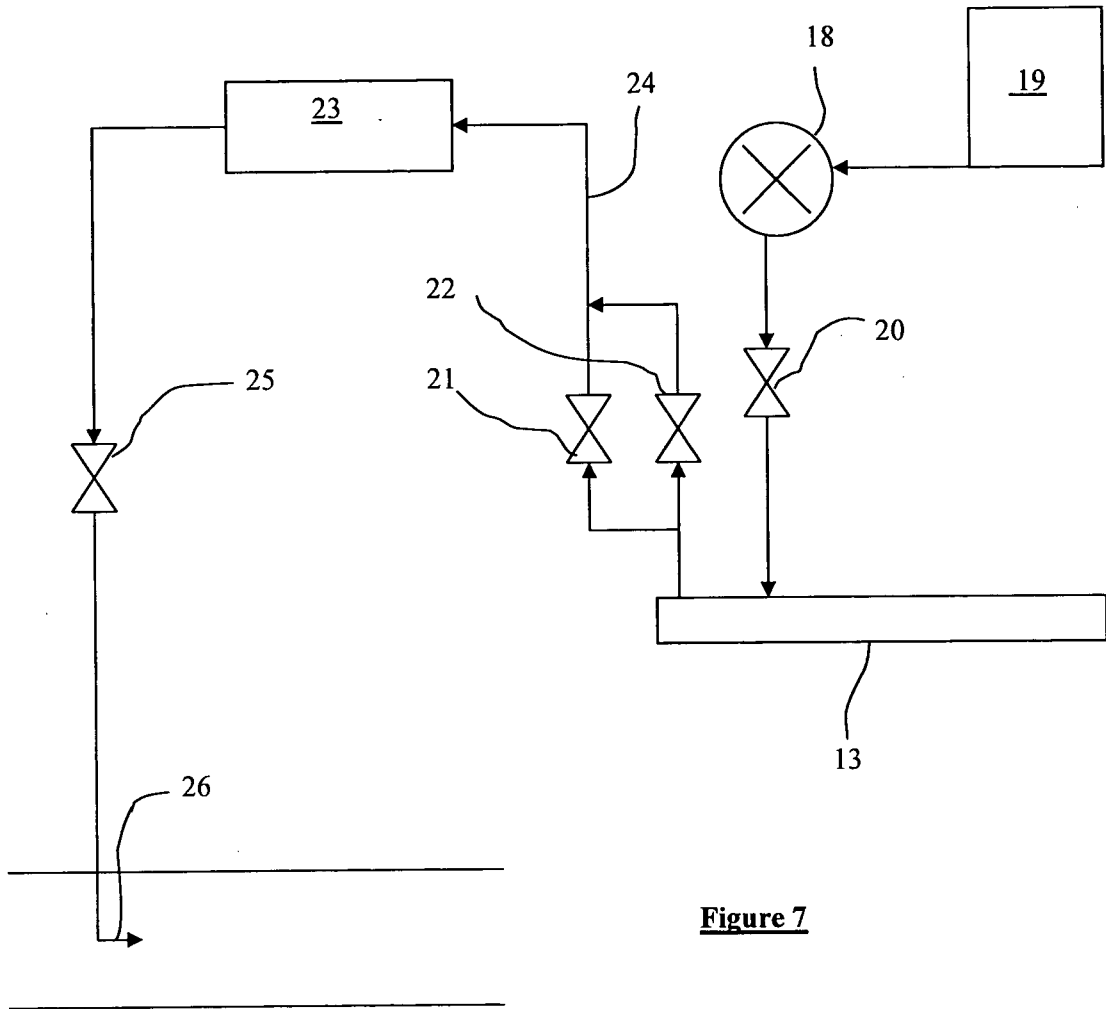


Figure 7

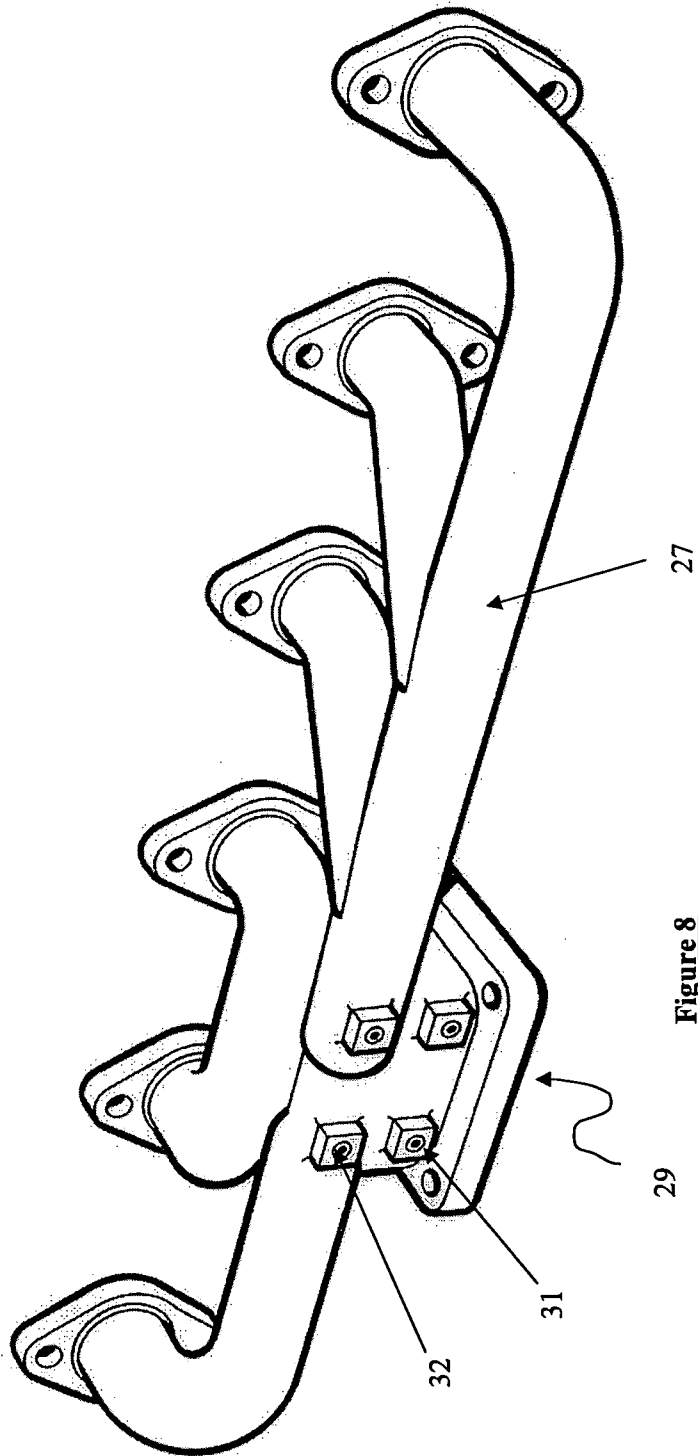


Figure 8

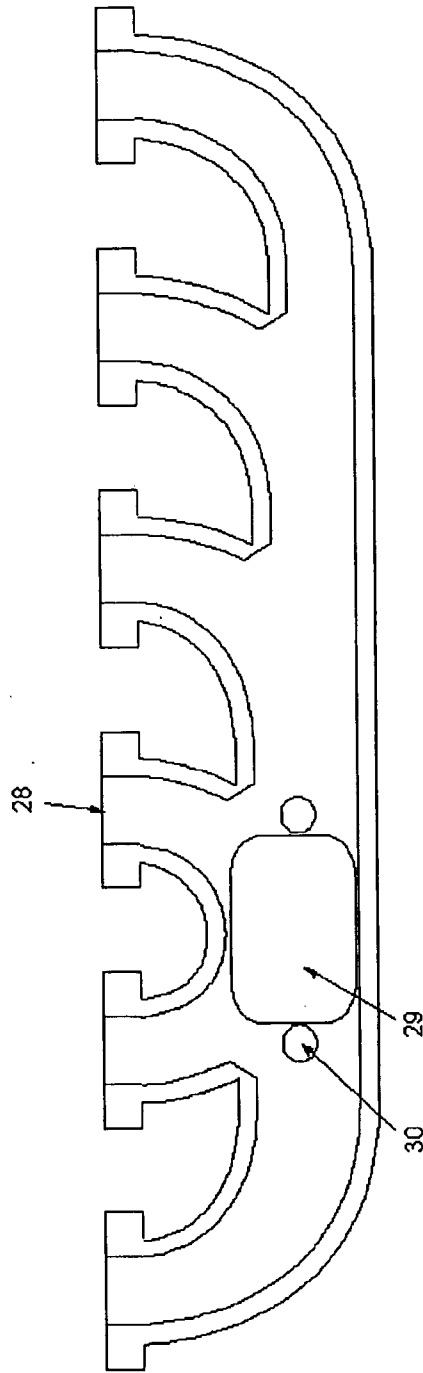


Figure 9

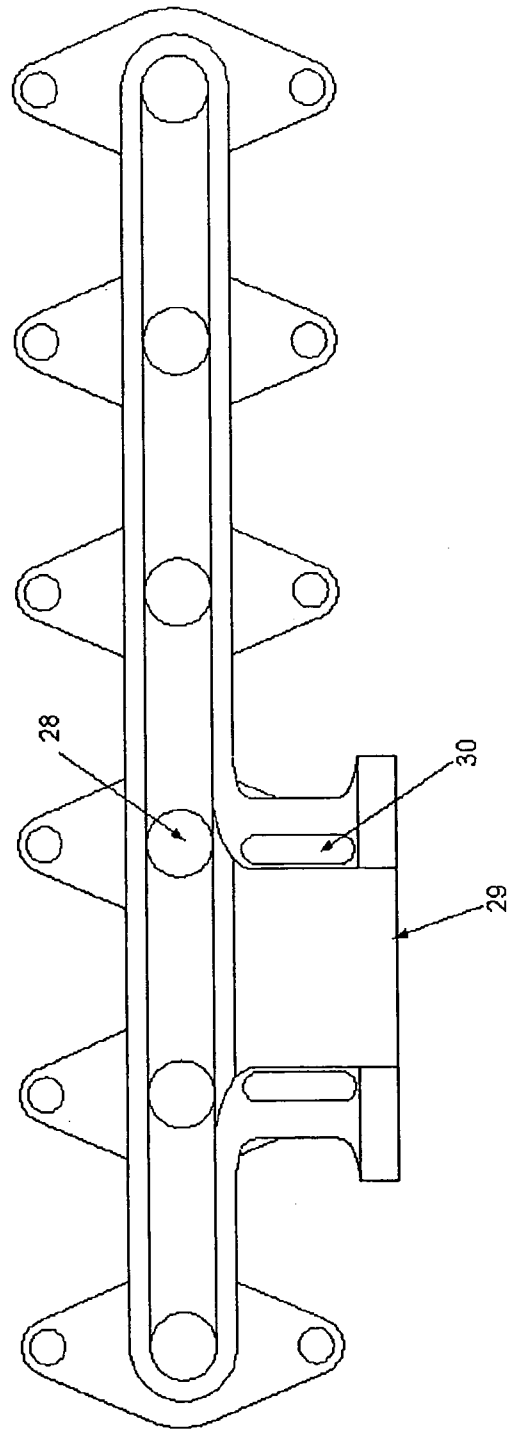


Figure 10

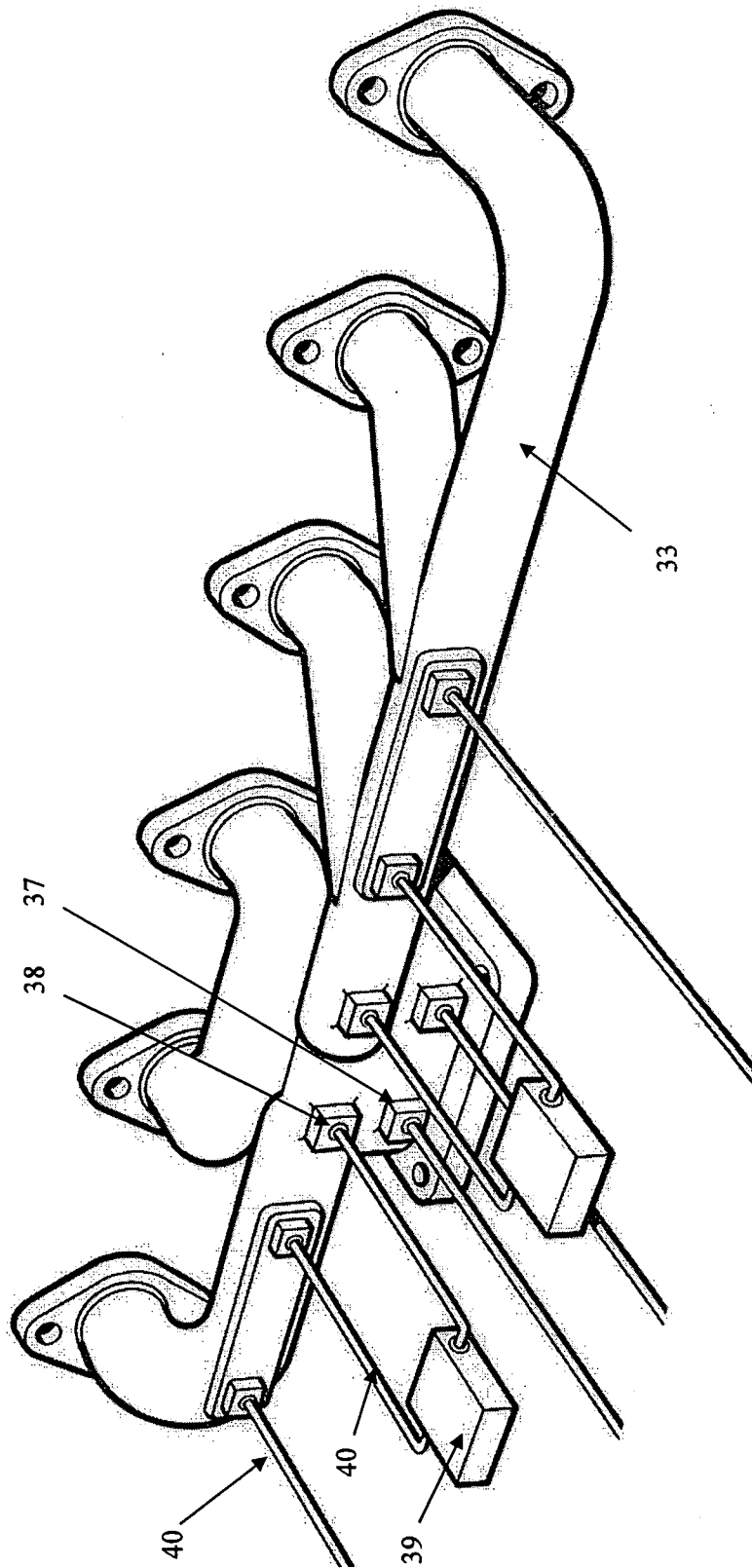


Figure 11

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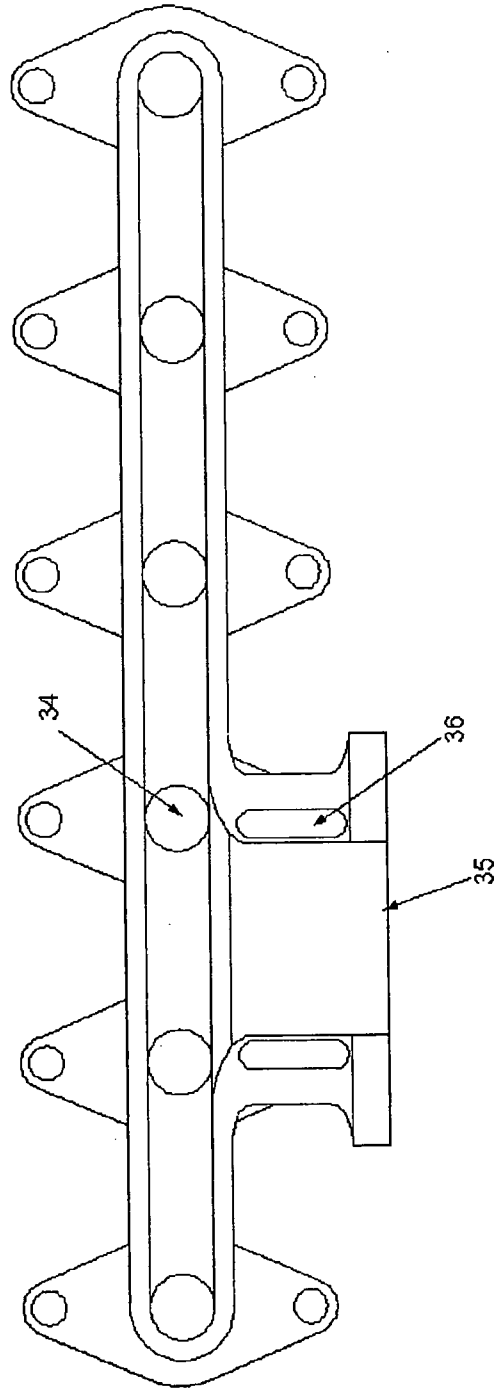


Figure 12

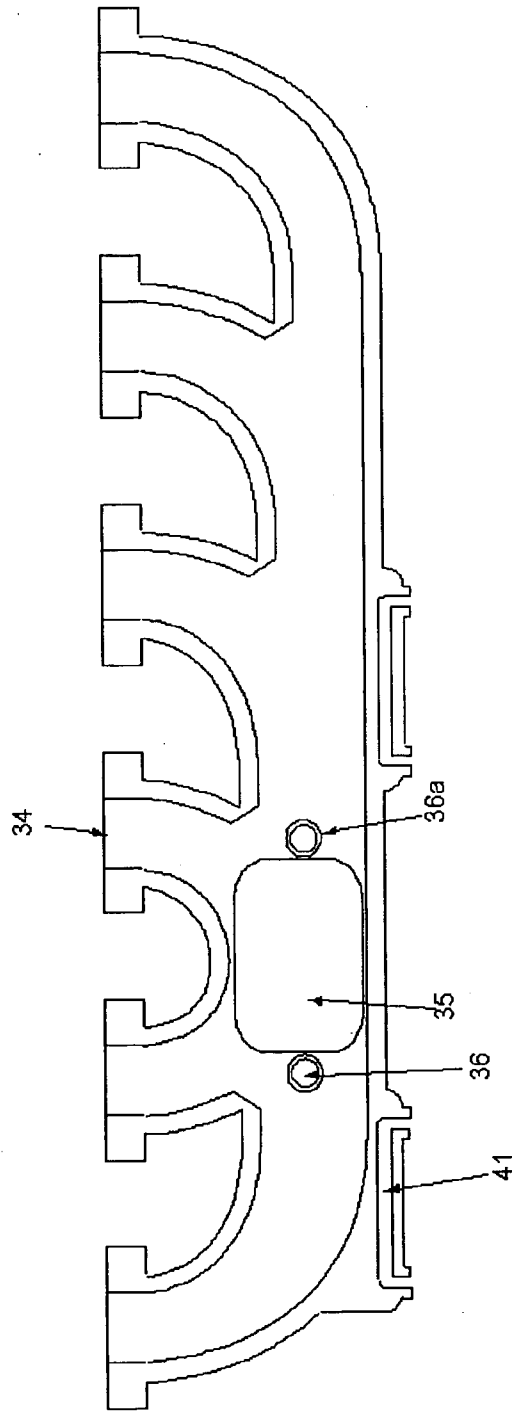


Figure 13

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2007/003115

A. CLASSIFICATION OF SUBJECT MATTER
 INV. F01N3/20 B01D53/90 B01D53/94

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
 F01N B01D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 968 464 A (PETER-HOBLYN JEREMY D [GB] ET AL) 19 October 1999 (1999-10-19)	29, 30
A	column 4, line 64 - column 5, line 43 column 6, line 63 - line 65 column 7, line 1 - line 6; figures 1,2	1, 27
X	WO 2004/079171 A (IMI VISION LTD [GB]; VIERKOTTER MARTIN [DE]; AVENS RUSSELL STUART [DE]) 16 September 2004 (2004-09-16)	29, 30
A	page 4, line 21 - line 30 page 12, line 19 - line 27; figure 9	1
X	EP 1 612 381 A (IVECO S P A [IT]) 4 January 2006 (2006-01-04)	1
	column 3, line 3 - column 4, line 11; figure 1	
	----- -/--	

Further documents are listed in the continuation of Box C.

See patent family annex.

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Date of the actual completion of the international search

4 December 2007

Date of mailing of the international search report

10/12/2007

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INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2007/003115

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>EP 1 481 719 A (HITACHI LTD [JP]; HITACHI HIGH TECH CORP [JP]; BABCOCK HITACHI KK [JP]) 1 December 2004 (2004-12-01) column 6, line 5 - column 10, line 36; figures 1,2</p> <p style="text-align: center;">-----</p>	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2007/003115

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WO 2004079171	A	16-09-2004	GB 2414692 A	07-12-2005
EP 1612381	A	04-01-2006	NONE	
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			US 2005013756 A1	20-01-2005