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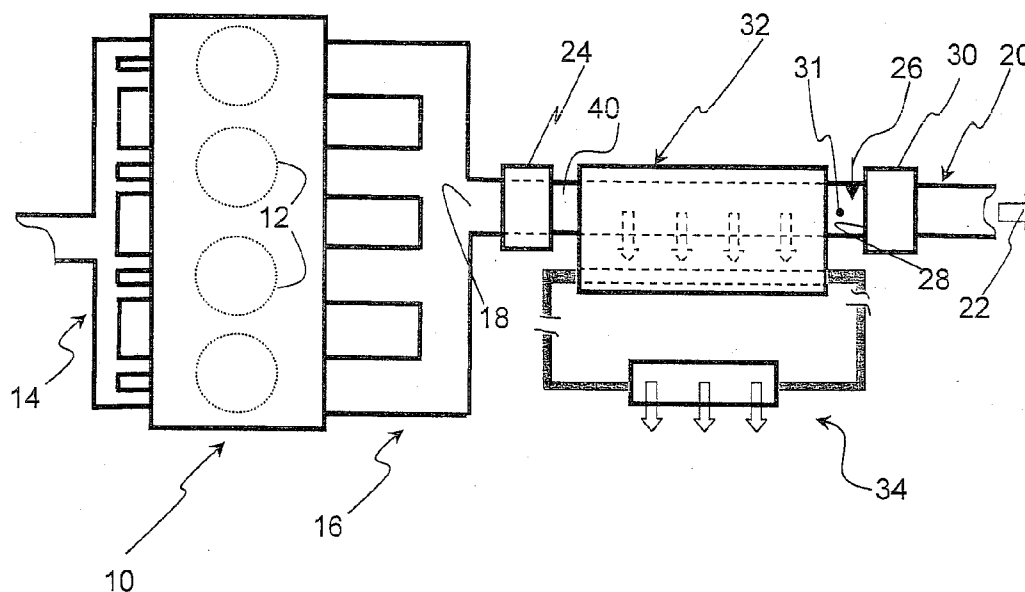
(19) **United States**(12) **Patent Application Publication**
MENDEZ et al.(10) **Pub. No.: US 2012/0144804 A1**(43) **Pub. Date: Jun. 14, 2012**(54) **METHOD AND DEVICE FOR CONTROLLING
THE TEMPERATURE OF EXHAUST GAS
FROM AN INTERNAL-COMBUSTION
ENGINE FLOWING THROUGH A MEANS OF
TREATING THE POLLUTANTS CONTAINED
IN THIS GAS****Publication Classification**(51) **Int. Cl.**
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F01N 3/10 (2006.01)(52) **U.S. Cl.** **60/274; 60/301**(75) **Inventors:** **Sylvain MENDEZ**, Saint-Etienne
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L'Ecole (FR)(73) **Assignee:** **IFP Energies Nouvelles**(21) **Appl. No.:** **13/309,680**(22) **Filed:** **Dec. 2, 2011**(30) **Foreign Application Priority Data**

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(57) **ABSTRACT**

The present invention relates to a method for controlling the temperature of exhaust gas circulating in an exhaust line (20) of an internal-combustion engine (10), said line comprising means (30) of treating the pollutants contained in this gas and heat exchange means (32) for cooling or heating said exhaust gas flowing through these pollutant treatment means.

According to the invention, the method consists in using evaporator (38) of a fluid circulation closed circuit (34) as heat exchange means (32).



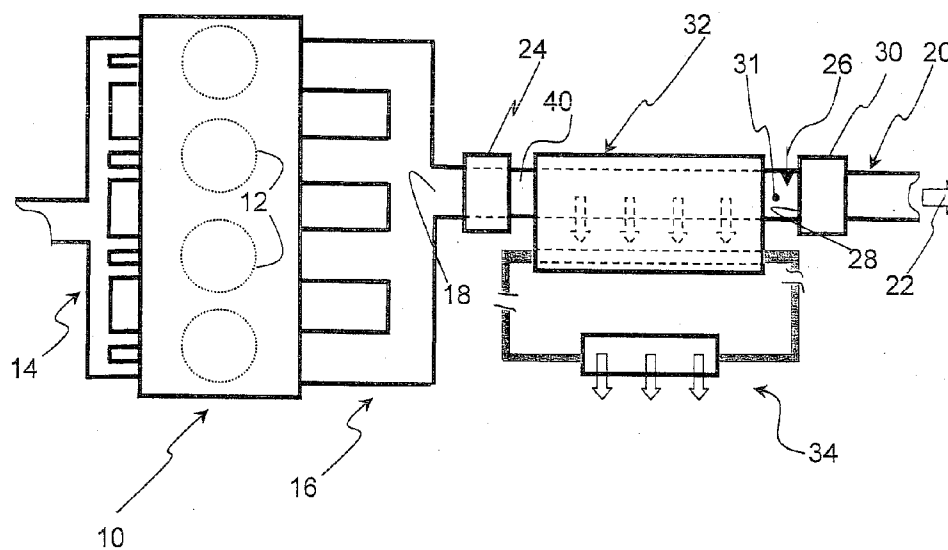


Figure 1

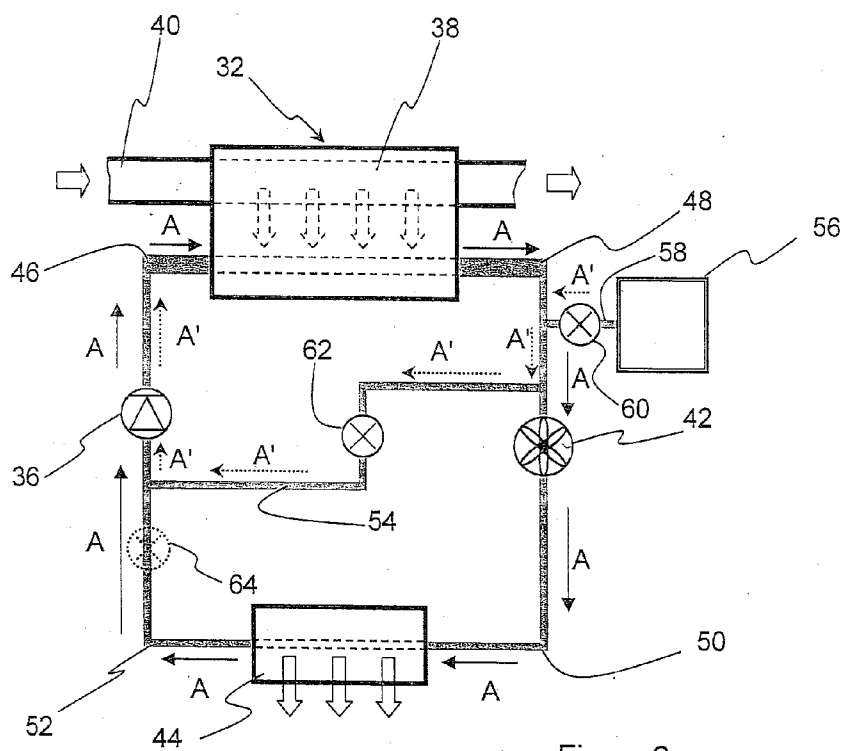


Figure 2

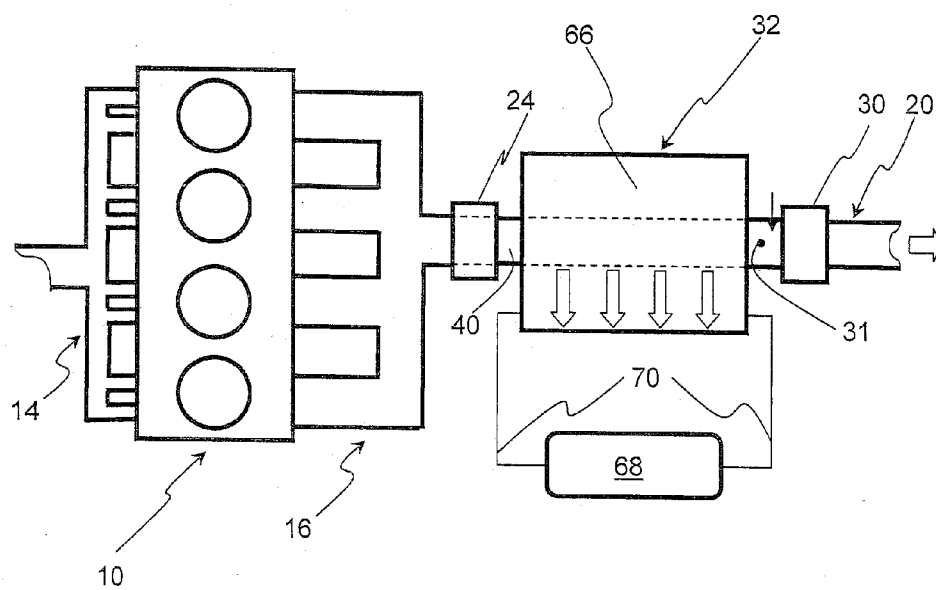


Figure 3

**METHOD AND DEVICE FOR CONTROLLING
THE TEMPERATURE OF EXHAUST GAS
FROM AN INTERNAL-COMBUSTION
ENGINE FLOWING THROUGH A MEANS OF
TREATING THE POLLUTANTS CONTAINED
IN THIS GAS**

FIELD OF THE INVENTION

[0001] The present invention relates to a method and to a device for controlling the temperature of exhaust gas from an internal-combustion engine, notably of Diesel type, flowing through a means of treating the pollutants contained in this gas.

BACKGROUND OF THE INVENTION

[0002] In order to comply with environmental standards and to meet the severization of these standards, such as the standards known as EURO VI, these pollutants, in particular the nitrogen oxides (NO and NO₂), more commonly referred to as NOx, contained in this exhaust gas, have to be treated prior to discharging it into the atmosphere.

[0003] As it is generally known, pollutant treatment devices are therefore installed on the exhaust line of vehicles.

[0004] This exhaust line comprises, from the exhaust manifold and in the direction of circulation of the exhaust gas along the line, a three-way catalyst, referred to as triple-effect catalyst, whose purpose is to treat, through oxidation, the unburnt hydrocarbons (HC) and the carbon monoxide (CO) contained in the exhaust gas, and an SCR (Selective Catalytic Reduction) catalyst for treating the NOx.

[0005] This SCR catalyst allows to selectively reduce the NOx to nitrogen through the action of a reducing agent. This agent, which is generally injected upstream from the catalyst, can be a hydrocarbon, hydrogen, carbon monoxide, ammonia or a compound generating ammonia through decomposition, such as urea.

[0006] The problem that arises with such a device is that the SCR catalyst has an operating temperature ranging from around 300° C. to around 500° C.

[0007] Now, it is not always possible to finely control the exhaust gas temperature because it greatly depends on the engine operating point. Thus, for high engine loads notably, the exhaust gas temperature can widely exceed 500° C. This high temperature, on the one hand, does not allow the catalyst to fulfil its NOx reduction function and, on the other hand, it can lead to a degradation of the constituent material of this catalyst and/or of the catalytic phases it comprises.

[0008] It is already known to arrange heat exchange means on the exhaust line and upstream from the SCR catalyst in order to cool the exhaust gas before it enters this catalyst.

[0009] A cooler through which the engine cooling fluid flows is therefore arranged on the exhaust line. This cooler allows to absorb the heat contained in the exhaust gas and thus to control the temperature of this gas so that it does not exceed the upper value of the operating temperature range of this catalyst.

[0010] This however notably involves the drawback of generating an increase in the temperature of the cooling fluid that is heated by the exhaust gas. Since this fluid is also used for cooling the engine and other accessories of this engine through an intercooler, it is therefore necessary to increase the capacity of this intercooler. In case of limited space for the intercooler, it is necessary to provide additional intercoolers

so as to bring this cooling fluid to a required temperature. This leads to a quite significant cost increase and to complexity of the engine general cooling circuit.

[0011] Furthermore, when the temperature of the gas is lower than that required to provide smooth operation of the catalyst, notably when starting the engine or after stopping this engine, the exhaust gas containing NOx is not treated by the catalyst and it is discharged into the atmosphere with the pollutants it contains.

[0012] The present invention aims to overcome the aforementioned drawbacks by means of a simple and economical device allowing to have exhaust gas at the required temperature to provide depollution treatment of this gas, whatever the operating conditions of the internal-combustion engine.

SUMMARY OF THE INVENTION

[0013] The present invention therefore relates to a method for controlling the temperature of exhaust gas circulating in an exhaust line of an internal-combustion engine, said line comprising means of treating the pollutants contained in this gas and heat exchange means for cooling or heating said exhaust gas flowing through these pollutant treatment means.

[0014] The method can consist in feeding a hot fluid into the evaporator so that it heats the exhaust gas.

[0015] The method can consist in using a hot fluid contained in a fluid storage means connected to the circuit.

[0016] The method can consist in connecting the storage means to the evaporator by means of a bypass line.

[0017] The invention also relates to a device for controlling the temperature of exhaust gas circulating in an exhaust line of an internal-combustion engine, said line comprising means of treating the pollutants contained in this gas and reversible heat exchange means for cooling or heating said exhaust gas flowing through these pollutant treatment means, characterized in that the reversible heat exchange means are an evaporator of a fluid circulation closed circuit.

[0018] The circuit can comprise a fluid storage tank.

[0019] The tank can be a thermally insulated tank.

[0020] The tank can comprise fluid heating means.

[0021] The circuit can comprise a bypass line for allowing the fluid from the tank into the evaporator.

[0022] The bypass line can comprise a throttling means.

[0023] The reversible heat exchange means can comprise at least one thermopile.

[0024] The thermopile can be connected to electric accumulators for supplying power thereto when heating the exhaust gas.

[0025] The pollutant treatment means can comprise a selective catalytic reduction catalyst.

BRIEF DESCRIPTION OF THE FIGURES

[0026] Other features and advantages of the invention will be clear from reading the description given hereafter by way of non limitative example, with reference to the accompanying figures wherein:

[0027] FIG. 1 is a diagram showing a device for controlling the temperature of exhaust gas from an internal-combustion engine according to the invention,

[0028] FIG. 2 is a more detailed view of a part of the device of FIG. 1, and

[0029] FIG. 3 is another diagram illustrating a variant of the device as shown in FIG. 1.

DETAILED DESCRIPTION

[0030] In connection with FIG. 1, internal-combustion engine 10, notably of Diesel type, comprises at least one cylinder 12, an intake manifold 14 and an exhaust manifold 16 allowing to collect the exhaust gas resulting from the combustion of a fuel mixture in the cylinders prior to sending it to inlet 18 of an exhaust line 20.

[0031] In FIG. 1, the exhaust line carries, in the direction of circulation of the exhaust gas from inlet 18 of this line to its outlet (symbolized by arrow 22), a three-way oxidation catalyst 24 arranged as close as possible to exhaust gas inlet 18, followed by an injector 26 for a reducing agent, urea here, arranged opposite inlet face 28 of an SCR catalyst 30. This line also carries an exhaust gas temperature detector 31 housed opposite and close to inlet face 28 of the SCR catalyst. This detector allows, in combination with the calculator any internal-combustion engine is usually provided with, to know the temperature of the exhaust gas entering this catalyst.

[0032] As more visible in FIG. 1, a reversible heat exchanger 32 is provided between the two catalysts to control the temperature of the exhaust gas reaching inlet face 28 of the SCR catalyst. Advantageously, this exchanger is arranged downstream from the three-way catalyst and upstream from the temperature detector.

[0033] This exchanger allows to cool the gas or to heat it so that its temperature is in the usual operating range of the SCR catalyst, generally between around 300° C. and around 500° C.

[0034] More precisely, in connection with FIG. 2, this exchanger is part of a fluid circulation closed circuit 34, more particularly of Rankine cycle type.

[0035] This circuit comprises a means 36 intended for circulation and compression of a working fluid, water here, circulating clockwise in this circuit (arrows A). This means, referred to as compressor, allows to compress this water and it is advantageously driven in rotation by any known means such as an electric motor (not shown).

[0036] This circuit comprises, after the compressor, a heat exchange means 38, an evaporator here, traversed by the compressed water that leaves it in compressed steam form.

[0037] This evaporator is arranged on portion 40 of exhaust line 20 contained between the two catalysts 24 and 30, preferably upstream from injector 26 and detector 31, so as to be able to cool the exhaust gas circulating in this portion or to heat it.

[0038] The person skilled in the art may consider any possible configuration for arranging this evaporator in direct or indirect connection with this exhaust line portion so as to provide the best heat exchange possible with the exhaust gas.

[0039] After this evaporator, the circuit also comprises an expander 42 receiving from this evaporator the high-pressure compressed steam that flows therefrom in form of low-pressure expanded steam.

[0040] This expander can be, by way of example, an expansion turbine whose rotor is driven in rotation by the steam. This rotor is advantageously connected to a device for converting the mechanical energy recovered to another energy, such as an electric generator for example.

[0041] The circuit also comprises a cooling exchanger 44 or condenser receiving the expanded low-pressure steam from the expander that is converted, at the outlet of this

condenser, to water in liquid form. This condenser is, in the example of FIG. 1, swept by a cooling fluid that is advantageously outside air at ambient temperature.

[0042] Fluid circulation lines allow to successively connect the various elements of this circuit so that the working fluid, in liquid or vapour form, circulates in the direction shown by the arrows. More precisely, this circuit comprises a line 46 between the compressor and the evaporator, a line 48 between the evaporator and the expander, a line 50 between the expander and the condenser, and a line 52 between the condenser and the compressor.

[0043] Furthermore, this circuit comprises a bypass line 54 that starts on line 48 between the evaporator and the expander, and ends on line 52 between the condenser and the compressor. Besides, an advantageously thermally insulated tank 56 is connected to line 48 by a connecting line 58 that ends on the portion of line 48 contained between the evaporator and the starting point of bypass line 54. This bypass line and connecting line 58 carry each a throttling means allowing to control the fluid circulation in these lines, such as a valve 60 and 62 respectively.

[0044] Tank 56 associated with lines 54 and 58, and with valves 60 and 62, provides reversibility of the heat exchange from the evaporator so as to turn the cooler function of this evaporator into a heat generator function for heating the exhaust gas circulating in portion 40.

[0045] When the engine is running, the calculator (associated with detector 31) can evaluate that the exhaust gas temperature is either excessive (above about 500° C.) or insufficient (below about 300° C.) to provide smooth running of SCR catalyst 30.

[0046] In cases where this temperature is excessive, circuit 34 is started so as to cool the exhaust gas circulating in portion 40 of line 20 while providing heat exchange between the gas circulating in this portion and evaporator 48.

[0047] More precisely, valves 60, 62 are in closed position for lines 54, 58 and the water circulates in this circuit in a conventional clockwise direction with respect to the figure (arrows A) under the effect of compressor 36. The compressed water leaving this compressor circulates in line 46 and ends into evaporator 38. This compressed water then flows through the evaporator by collecting the heat carried by the exhaust gas, which is transmitted to this evaporator. Under the effect of this heat from the gas, the temperature thereof is lowered and the water is heated, thus leaving the evaporator in form of hot compressed steam. The steam then flows through expander 42 while transmitting thereto the energy it contains. The expanded steam leaving this expander through line 50 flows through condenser 44, which it leaves in form of liquid water. This liquid water is finally brought through line 52 to compressor 36 in order to be compressed.

[0048] Circuit 10 is thus kept in operation until the temperature of the exhaust gas reaching the inlet face of the SCR catalyst is the temperature required for operation of this catalyst.

[0049] Just before the circuit is stopped, valve 60 of connecting line 58 is switched to an open position so that the steam leaving evaporator 38 is fed into thermally insulated storage tank 56 where it is kept at high temperature.

[0050] This valve is then set to a closed position as soon as the tank is filled with this steam.

[0051] Conversely, in case of an insufficient exhaust gas temperature for operation of SCR catalyst 30, notably when

starting the engine, valves **60** and **62** are set to an open position for lines **58**, **54** and compressor **36** is started.

[0052] In this configuration, the high-temperature steam contained in tank **56** is discharged therefrom through connecting line **58** and fed into line **48**. Under the effect of compressor **36**, this steam circulates clockwise with respect to arrows A' in FIG. 1.

[0053] The steam thus circulates in a portion of line **48**, then in bypass line **54** before it reaches the compressor inlet. This steam leaves the compressor and enters evaporator **38**. This evaporator thus inverts its initial function of collecting the heat contained in the gas. More precisely, the evaporator turns into a heat generator by yielding the heat contained in the steam to the exhaust gas circulating in portion **40** of the exhaust line. This allows the gas to be heated by thermal exchange. It is therefore possible to rapidly increase the gas temperature and to considerably reduce the time required to obtain the suitable exhaust gas temperature for operation of the SCR catalyst.

[0054] Advantageously, an additional valve **64** (in dotted line in FIG. 1) can be provided on line **50** or **52** so that, in closed position for these lines, the steam cannot flow through condenser **44**.

[0055] Of course, this additional valve is in an open position for lines **50** or **52** in the configuration where this circuit is used for cooling the exhaust gas.

[0056] Thus, by means of simple layouts of this closed circuit, it is possible to either cool the exhaust gas or to reversibly heat it using the same evaporator.

[0057] Of course, without departing from the scope of the invention, it is possible to use, instead of the thermally insulated tank, a tank provided with means for heating the liquid it contains, such as heating resistors, a burner, etc.

[0058] FIG. 3 shows a variant of the reversible heat exchange device **32** provided between the two catalysts **24**, **30** to control the temperature of the exhaust gas reaching inlet face **28** of SCR catalyst **30**.

[0059] This device comprises a thermopile or a succession of thermopiles **66** arranged on portion **40** of exhaust line **20** between three-way catalyst **24** and SCR catalyst **30**.

[0060] Generally, this thermopile allows to recover the heat energy contained in the exhaust gas and to convert it, notably through Seebeck effect, to an electric energy that is then stored in electric accumulators **68** through conductors **70**.

[0061] Of course, as in FIG. 1, the person skilled in the art can consider all the possible configurations for arranging this thermopile in direct or indirect connection with this exhaust line portion so as to provide the best possible heat exchange with the exhaust gas.

[0062] Thus, in cases where the exhaust gas temperature is excessive (above about 500° C.), the thermopile is active to provide heat exchange between the gas circulating in portion **40** of line **20** and this thermopile, by collecting the heat contained in this gas. The exhaust gas is therefore cooled and the thermopile collects the heat energy contained in the exhaust gas stream so as to convert it to electric energy that is stored in accumulators **68**.

[0063] Once the exhaust gas temperature is stabilized, operation of the thermopile can be stopped.

[0064] In the opposite case where the exhaust gas temperature is below its minimum threshold value required to provide operation of SCR catalyst **30**, thermopile **66** is supplied with power by accumulators **68**.

[0065] This power supply has the effect of heating the thermopile that can then transfer its heat to the exhaust gas circulating in portion **40** of line **20**.

[0066] Similarly, once the exhaust gas temperature has reached the desired value, the thermopile supply is stopped so as to stop heating the exhaust gas, which has become unnecessary.

[0067] Thanks to the reversibility of the thermopile heat exchange, the exhaust gas can be cooled or heated so that its temperature is in the usual operating range of the SCR catalyst.

1) A method for controlling the temperature of exhaust gas circulating in an exhaust line of an internal-combustion engine, said line comprising means of treating pollutants contained in this gas and heat exchange means for cooling or heating said exhaust gas flowing through these pollutant treatment means, characterized in that it consists in using evaporator of a fluid circulation closed circuit as heat exchange means.

2) A method as claimed in claim 1, characterized in that it consists in feeding a hot fluid into the evaporator so that it heats the exhaust gas.

3) A method as claimed in claim 2, characterized in that it consists in using a hot fluid contained in a fluid storage means connected to the circuit.

4) A method as claimed in claim 1, characterized in that it consists in connecting storage means to evaporator by means of a bypass line.

5) A device for controlling the temperature of exhaust gas circulating in an exhaust line of an internal-combustion engine, said line comprising means of treating pollutants contained in this gas and reversible heat exchange means for cooling or heating said exhaust gas flowing through these pollutant treatment means, characterized in that the reversible heat exchange means are an evaporator of a fluid circulation closed circuit.

6) A device as claimed in claim 5, characterized in that circuit comprises a storage tank for a hot fluid.

7) A device as claimed in claim 6, characterized in that the tank is a thermally insulated tank.

8) A device as claimed in claim 6, characterized in that the tank comprises fluid heating means.

9) A device as claimed in claim 5, characterized in that circuit comprises a bypass line for allowing the fluid from the tank into evaporator.

10) A device as claimed in claim 9, characterized in that bypass line carries a throttling means.

11) A device as claimed in claim 5, characterized in that the pollutant treatment means comprise a selective catalytic reduction catalyst.

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