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(54) INTERNAL COMBUSTION ENGINE COMPRISING A REDUCING AGENT PRODUCTION UNIT AND OPERATING METHOD THEREFOR

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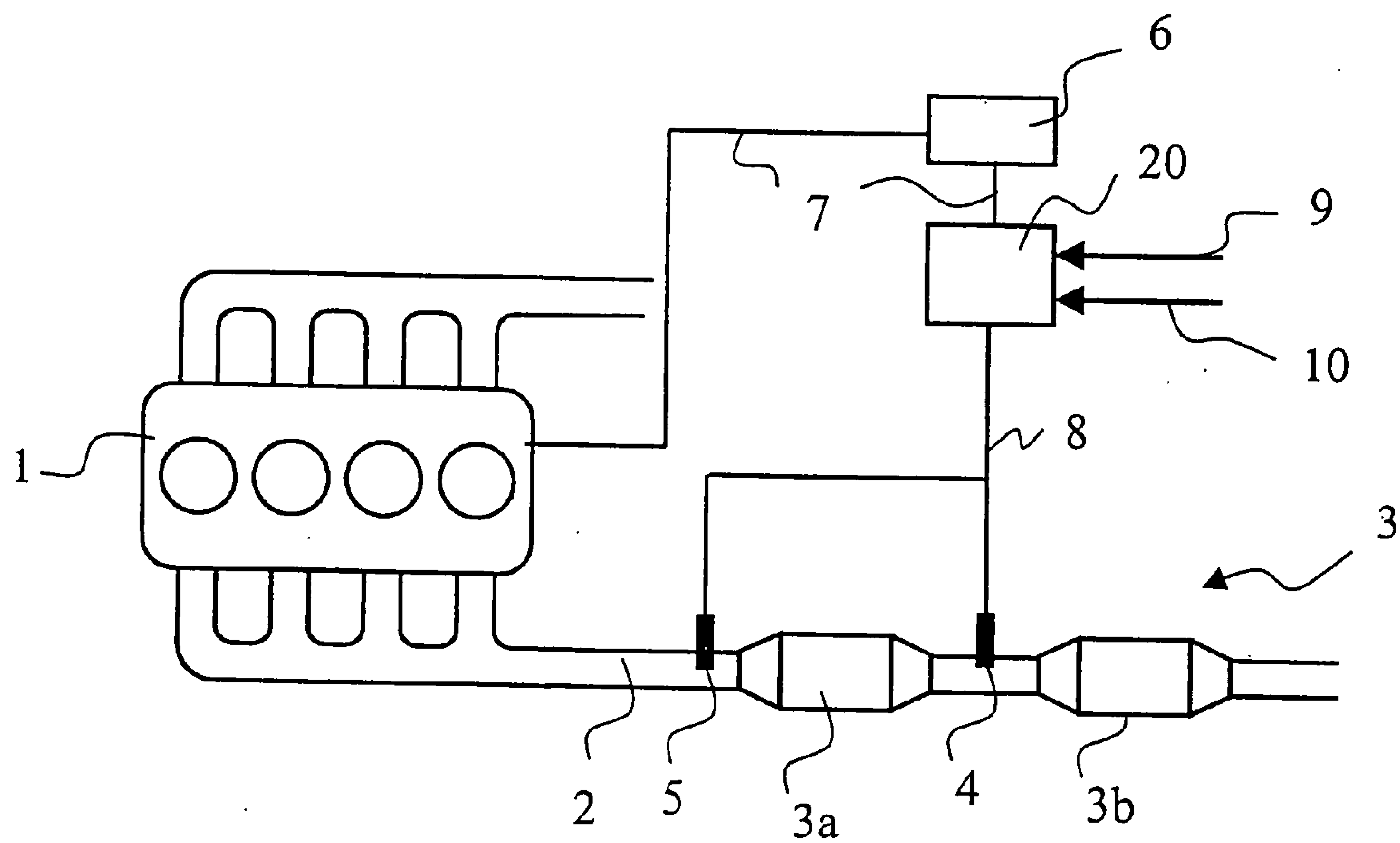
(57) **ABSTRACT**

An internal combustion engine with a reducing agent-generating unit for generation of an H_2-containing and/or NH_3-containing reducing gas, which can be added to an exhaust gas line upstream from an NO_x reducing catalytic converter, and a procedure for the operation of such an internal combustion engine are proposed. The reducing agent-generating unit has an NO_x generation step and an H_2 generation step in serial arrangement. NH_3 is formed at least temporarily by chemical reaction by the reducing agent-generating unit from NO_x produced in the NO_x generation step. The invention is applicable in motor vehicles, especially in passenger vehicles with Diesel engines.



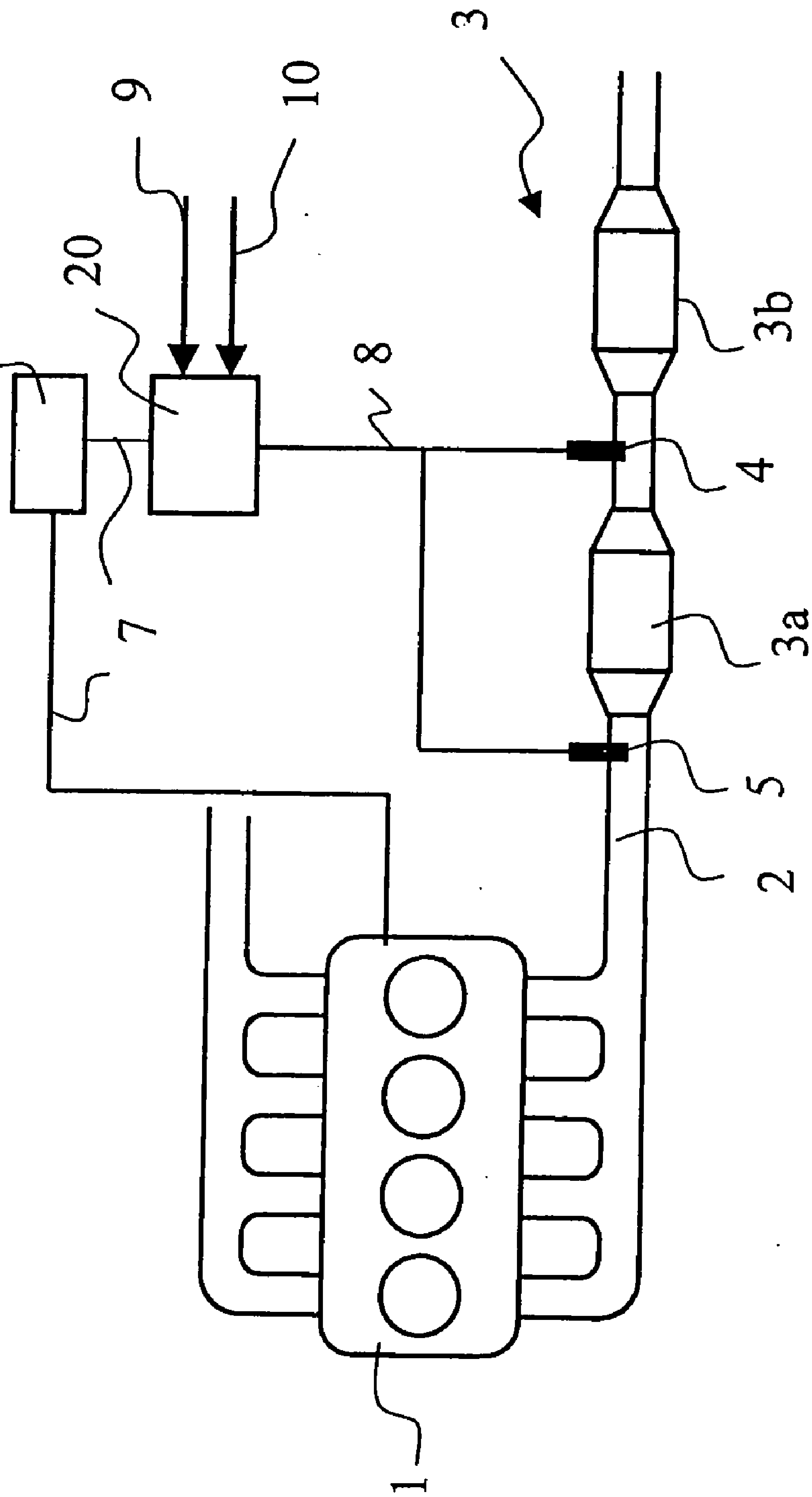


Fig. 1

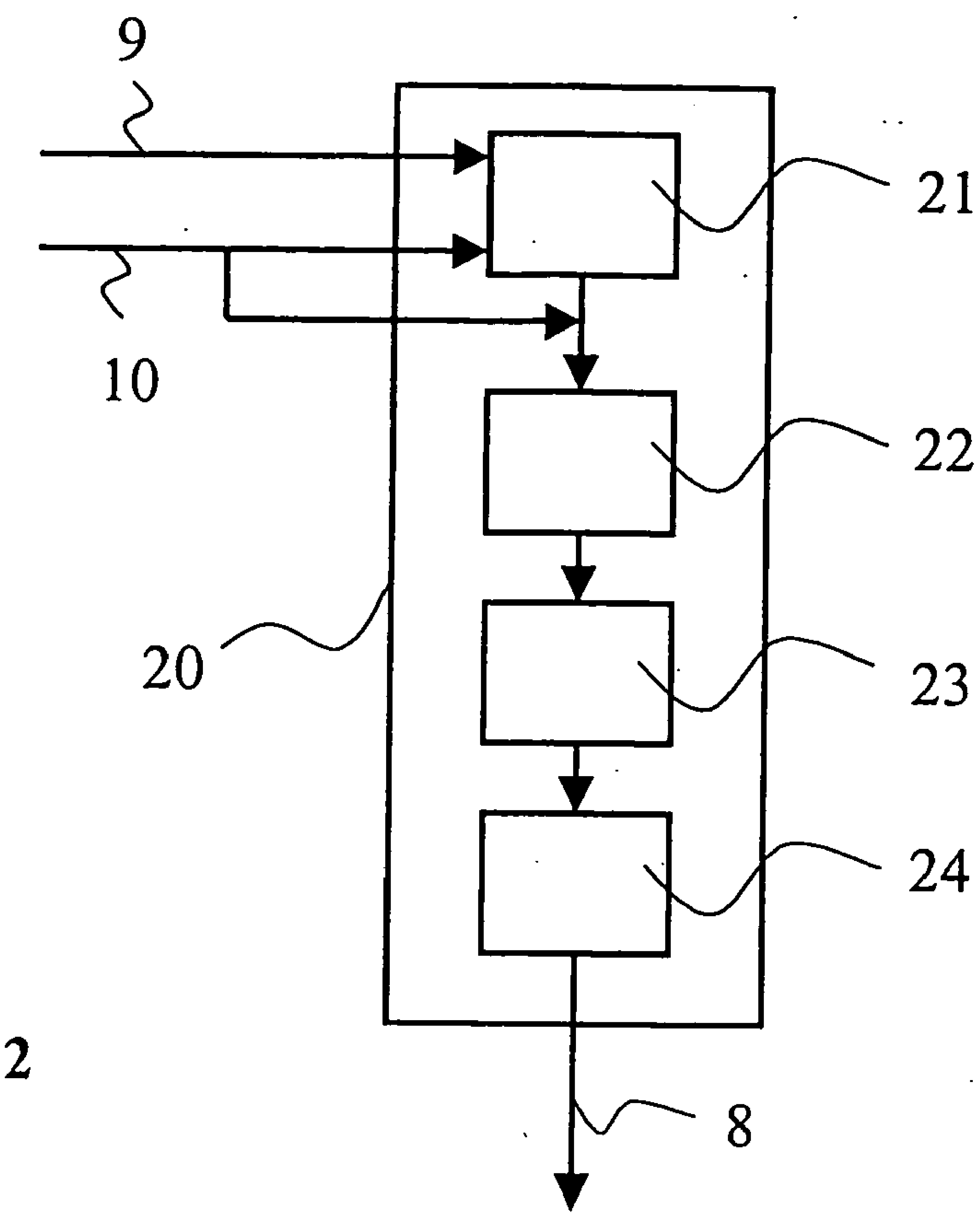


Fig. 2

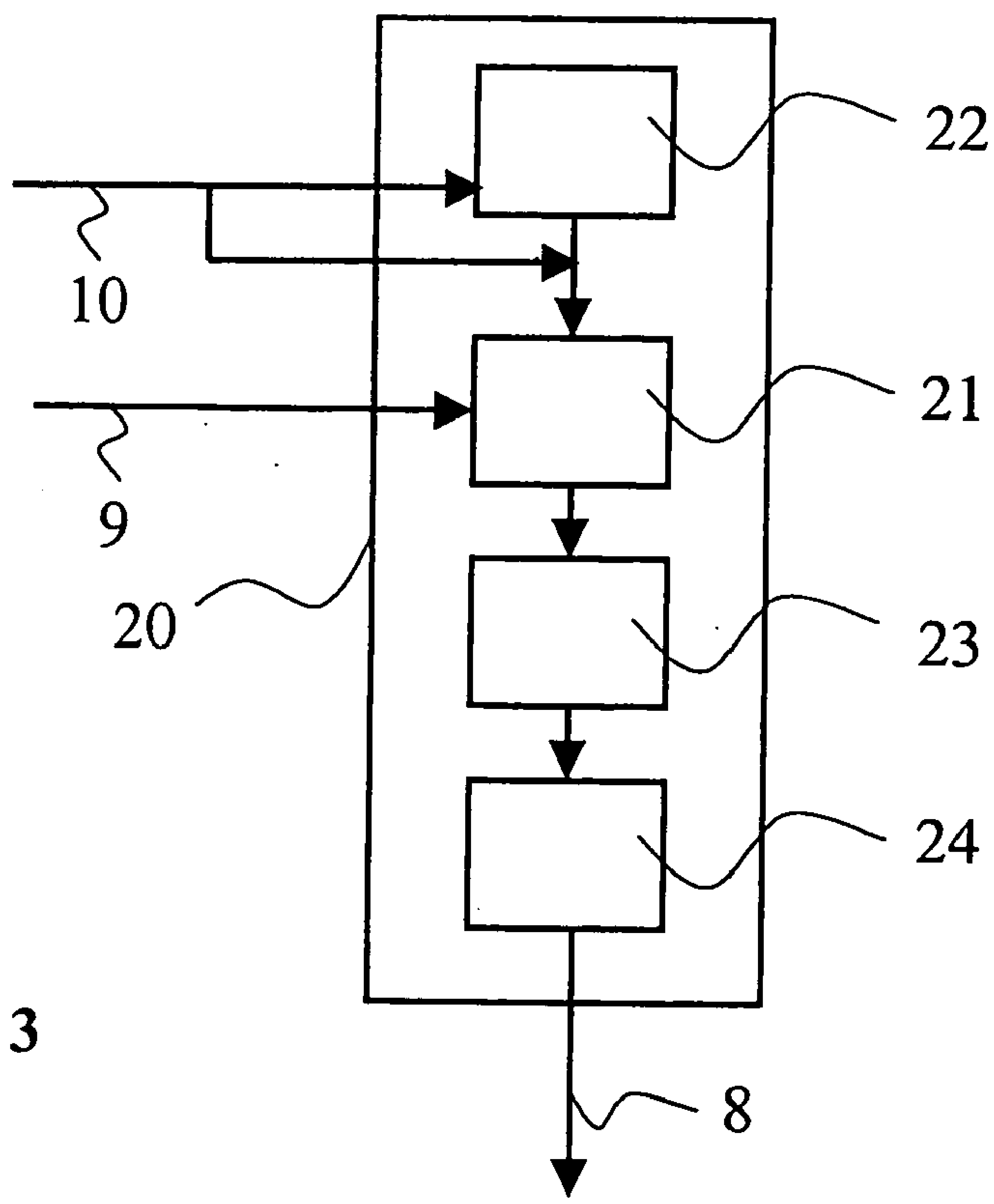


Fig. 3

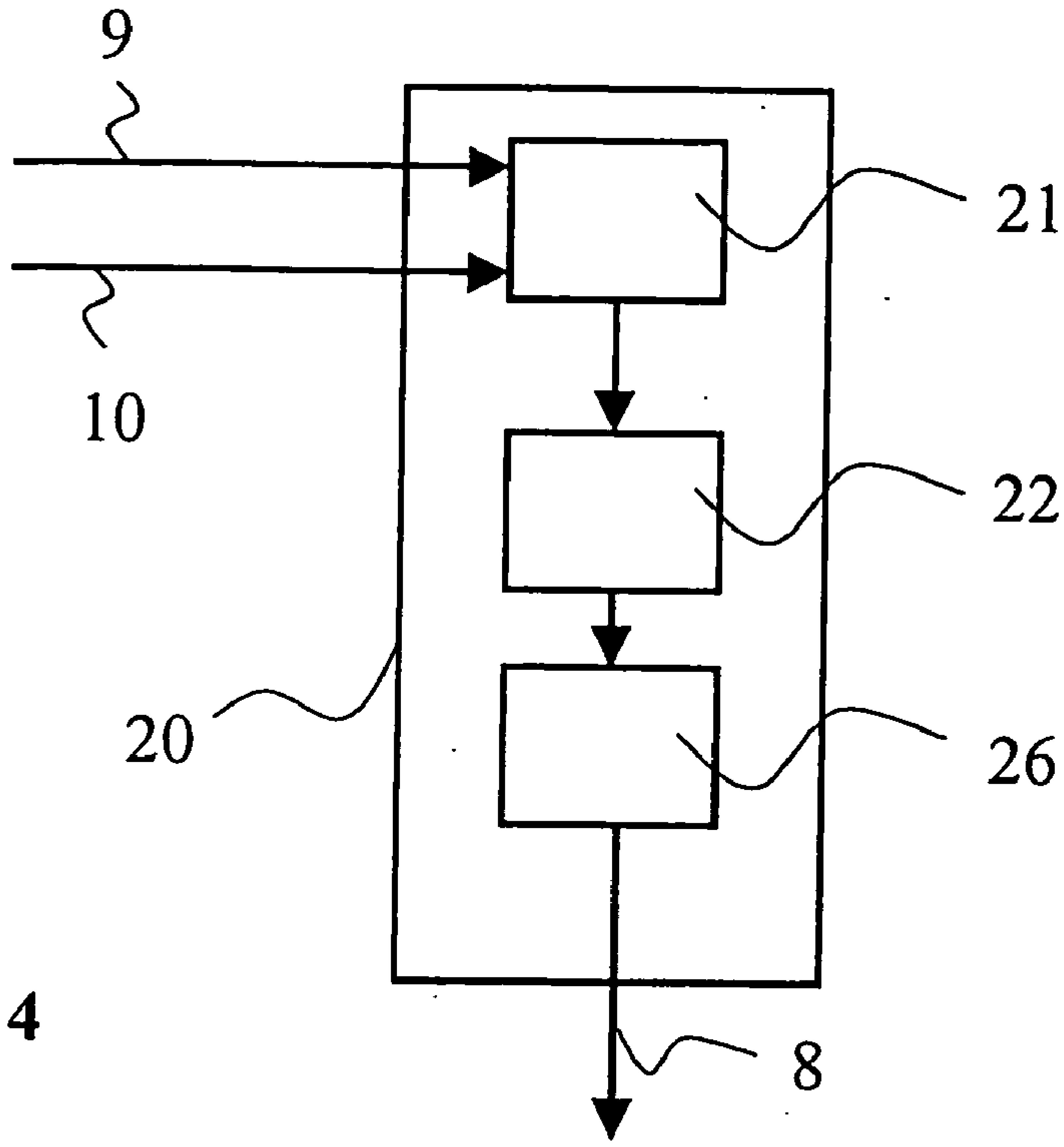


Fig. 4

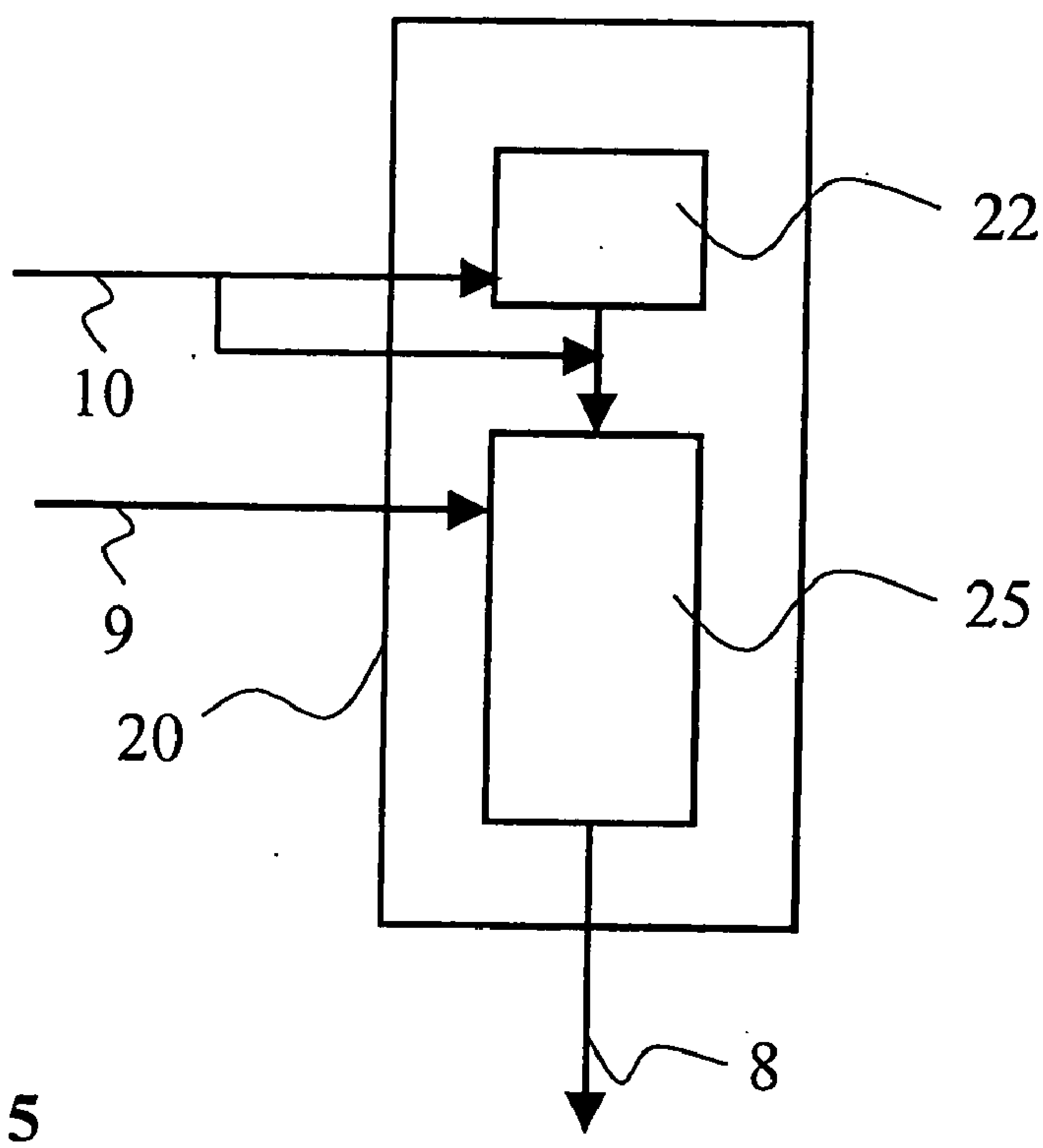


Fig. 5

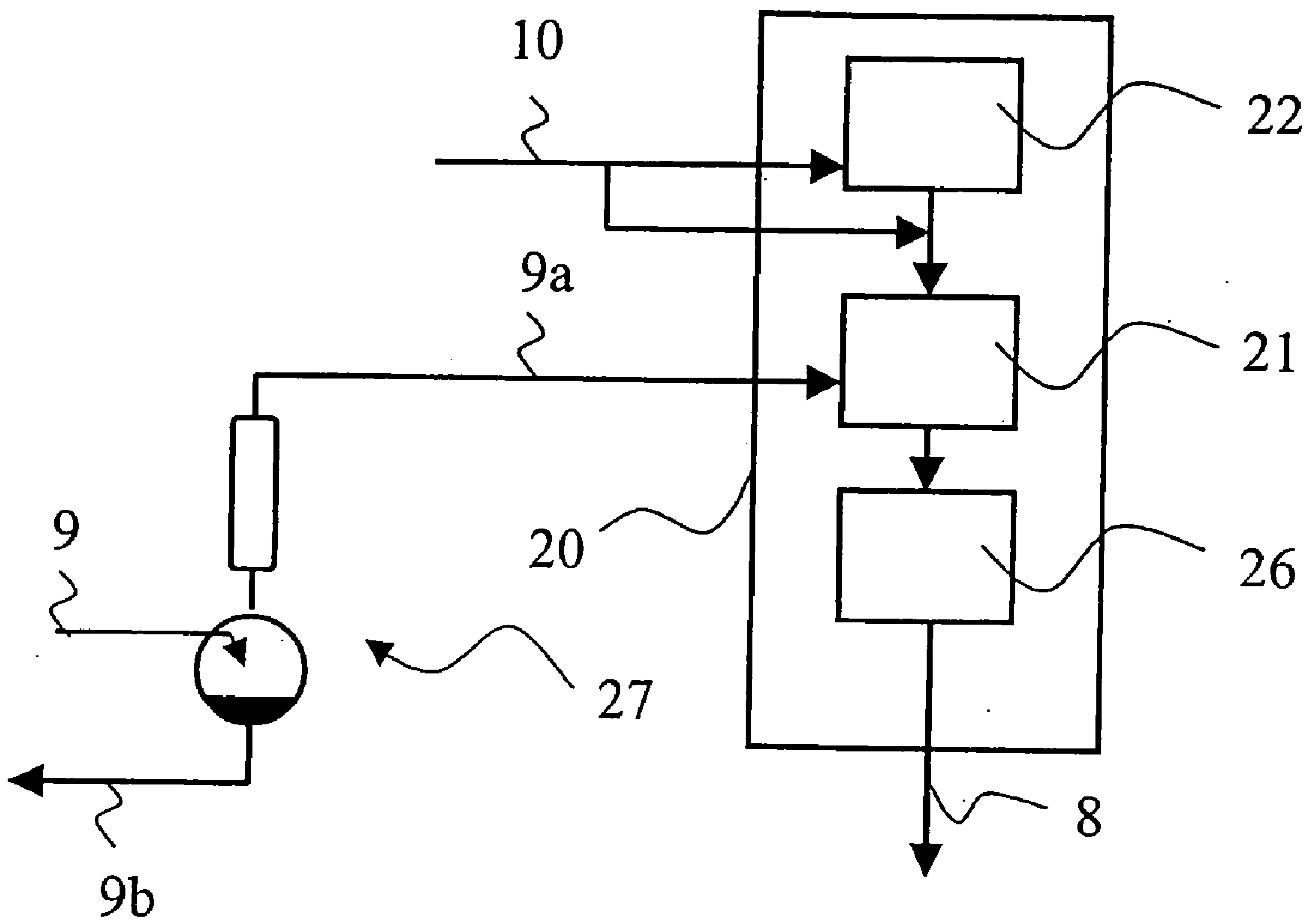


Fig. 6

INTERNAL COMBUSTION ENGINE COMPRISING A REDUCING AGENT PRODUCTION UNIT AND OPERATING METHOD THEREFOR

BACKGROUND AND SUMMARY OF THE INVENTION

[0001] The invention concerns an internal combustion engine with a reducing agent-generating unit and an operating method for the engine.

[0002] Non-published German patent application 10128414.4 describes an internal combustion engine with reducing agent-generating unit. The reducing agent-generating unit serves for producing an H_2-containing, and NH_3-containing reducing gas, which can be added upstream of an NO_x catalytic converter to the exhaust gas line of the internal combustion engine. An HC-containing (HC=hydrocarbon) fuel, as well as air and/or exhaust gas can be supplied to the reducing agent-generating unit. The generation of the H_2 portion, and the NH_3 portion in the reducing gas takes place in parallel controlled units, which makes the utilization of circuit components and the utilization of an intermediate storage unit necessary.

[0003] In contrast, an objective of this invention is to provide an internal combustion engine with a reduction-generating unit and an operating method for this, by means of which reducing agents for effective exhaust gas cleaning can be provided in a manner simple as to construction and process engineering.

[0004] This objective is accomplished in accordance with the invention.

[0005] The internal combustion engine of the invention includes a reducing agent-generating unit which has an NO_x generation step and an H_2 generation step in serial arrangement. The serial arrangement allows for a constructionally simple coupling of the generation steps with a low number of control valves, and independent of each other to a high degree, and therefore an easy to control operation of the generation steps. The NO_x produced by the NO_x generation step may be reduced as required by reducing the H_2 from the H_2 generation step to NH_3. Hereby, in connection with a suitable exhaust gas catalytic converter, an effective reducing agent for removing the nitrogen oxides present in the exhaust gas of the internal combustion engine is available. The H_2 produced by the H_2 generation step may also be utilized for the catalytic reduction of the nitrogen oxide contents in exhaust gas, especially at low temperatures.

[0006] The H_2 generation step is preferably realized as a POX reactor (POX=partial oxidation). By the appropriate selection of the operating conditions of the POX reactor, the composition of the product gas may be purposefully set, so that for example a product gas rich in H_2, or a product gas rich in cracked short-chain hydrocarbons is obtained. Since short-chain hydrocarbons or hydrogen are or is more effective with respect to NO_x reducing than long-chain hydrocarbons, especially at low temperatures, a mineral oil used as fuel for the internal combustion engine may be turned into a more efficient reducing agent for nitrogen oxides by means of such a reactor. Furthermore, the various temperature ranges of the effectiveness of the reducing agents producible by the reducing agent-generating unit may also be utilized, and the composition of the reducing gas may be adapted to the temperature of the NO_x reducing catalytic converters. An NO_x reduction is thereby made possible in a wide temperature range.

[0007] The H_2 yield of the H_2 generation may be increased by including a water gas shift reaction ($CO+H_2O$ ---->CO_2+H_2), or by a steam-reforming reaction ($HC+H_2O$ ---->CO_2+H_2). These may also take place in the H_2 generation step, or in a separate a reaction step preferably downstream from the generation step. The water necessary for the run of the water gas shift reaction, or the steam reforming reaction may be added to the relevant educt gas. If exhaust gas is added to the reducing agent-generating unit, the precondition for the run of the water gas shift reaction, or the steam reforming reaction, is already a given because of its water content.

[0008] Because of the easy oxidizability of the H_2 produced by the reducing agent-generating unit, in addition a quick heating up of catalytic converters in the exhaust gas string can be achieved. By adding the produced H_2 input of an exhaust gas catalyst, a rapid start-up of this catalytic converter may be achieved, which is of special importance in the reduction of pollutant emission at cold start. Similarly, catalytic converters may be effectively operated under thermally unfavorable conditions, such as in an underfloor position of a motor vehicle.

[0009] With the largely self-sufficiently operating reducing agent-generating unit, which is largely independent of the operation of the internal combustion engine, the reducing agent can thereby be made available on board of the associated motor vehicle and utilized for pollutant reduction. Since the reducing agent-generating unit can only be fed by the fuels, which are available on board of the motor vehicle anyhow, additional fuels and their storage become, or intermediate storage becomes, superfluous. Furthermore, the necessity is largely eliminated of converting the operation of the internal combustion engine for providing reducing agents for the NO_x reduction, e.g. to a rich combustion, which is associated with difficulties especially in Diesel engines. Overall, therefore, a reduction of the pollutant contents in exhaust gas is made possible in a constructionally simple manner, which is largely independent of the operation of the internal combustion engine.

[0010] In a refinement of the invention, the NO_x generation step is downstream from the H_2 generation step. This arrangement may offer benefits in the operation of the reducing agent generation. For example, the reducing gas flowing out of the upstream H_2 generation step in a hot state may cool down when passing through the NO_x generation step, so that the subsequent components are not being stressed too much thermally.

[0011] In a further refinement of the invention, the NO_x generation step is upstream of the H_2 generation step. This arrangement may also offer benefits in the operation of the reducing agent generation. For example, the gas flowing out of the upstream NO_x generation step may be utilized for controlling the process taking place in the downstream H_2 generation step.

[0012] In a further refinement of the invention an NH_3 generation step is arranged downstream from the NO_x generation step. The NH_3 generation step serves the on-board generation of NH_3, preferably adjusted to the requirements, so that this reducing agent does not have to be carried in a storage container for NO_x reduction.

[0013] In a further refinement of the invention, a fractionating unit is arranged to the reducing agent-generating unit in such a way that low-boiling components of a fuel used for operating the internal combustion engine are separable from the fractionating unit, which can be supplied to the H_2 generation step. This embodiment has the advantage that a reducing agent-generating unit realized, for example, as POX reactor, is easier to operate. The low-boiling components separated from the fuel are better and more completely cracked by the POX reactor. Furthermore, the formation of soot and condensation problems in the POX reactor may largely be prevented and the operating temperatures can be reduced. The degree of efficiency and the H_2 yield of the partial hydrocarbon oxidation can also be improved. Furthermore, by the fractioning largely sweet fuel components may be separated. The H_2 generation step is therefore only supplied with low-boiling fuel components, which are free of sulphur, so that sulphur poisoning is minimized.

[0014] In a further refinement of the invention, the NO_x generation step is operable in two operating modes with the H_2 generation step, such that in the first operating mode of the NO_x generation step, an NO_x-containing gas can be produced, and in the second operating mode an H_2-containing gas and NH_3-containing gas can be produced by the reducing agent-generating unit. This refinement allows an operation of the reducing agent-generating unit advantageously according to the need. In periods of time during which the component of the reduction gas is not needed, the operation of respective generation unit may be stopped.

[0015] In a further refinement of the invention an NO_x intermediate storage unit is arranged downstream from the NO_x generation step. In this embodiment, the NO_x generation step may also be operated with a low degree of efficiency. The NO_x available only in small concentrations in the product gas is accumulated in the NO_x intermediate storage unit, and after a certain time is available in large amounts for the reaction into NH_3.

[0016] In a further refinement of the invention, the NO_x intermediate storage unit is designed for the reaction of stored NO_x with H_2 into NH_3. With this double function of NO_x storage and formation of NH_3, the reducing agent-generating unit can have an especially compact design. In particular a NO_x storage catalytic converter may be used as an intermediate NO_x storage unit. An NO_x storage catalytic converter optimized, for example, by an increased rhodium content, with respect to the function of NO_x formation can be used within the framework of the invention.

[0017] In a further refinement of the invention, the H_2 generation step is realized for the reaction of the NO_x supplied into NH_3. If the H_2 generation step is simultaneously supplied with NO_x from the upstream arranged NO_x generation step, and HC-containing fuel supplied thereto, in one single, preferably catalytic operation, H_2 as well as NH_3 can be produced. In the partial hydrocarbon oxidation taking place under reducing conditions, the reduction of NO_x into NH_3 is preferred due to thermodynamic reasons, because of which this reduction step can be put together in an advantageous fashion in one operation with the H_2 generation. Thus, an NH_3 and H_2-containing reducing gas is produced in one operation. Hereby, the generation of the NH_3 and H_2-containing reducing gas is done preferably continuously.

[0018] In a further refinement of the invention, the NO_x generation step is designed for the generation of NO_x from air and/or oxygen-containing exhaust gas. Preferably, NO_x is produced in the NO_x generation step in a plasma process by an electric arc, or by a corona discharge. In conjunction with the downstream arranged reduction of NO_x thereby NH_3 is exclusively produced from components of the air and the carried fuel, and therefore the storage of an NH_3 releasing substance, such as urea, may be eliminated.

[0019] In a further refinement of the invention, the reducing NO_x catalytic converter has a denox catalytic converter step for the reaction of NO_x with H_2, and an SCR catalytic converter step for the reaction of NO_x with NH_3. In both cases, the NO_x reduction may take place in lean exhaust gas conditions, which is the reason why the internal combustion engine is preferably operated continuously lean, and so that the full consumption benefit of the lean operation can be taken advantage of. In addition it is possible to benefit from the various temperature ranges of the efficiency of the two catalytic converter steps, which is why an efficient nitrogen oxide reduction can be achieved in a wide temperature range.

[0020] The procedure according to the invention is characterized by the following operations:

a) Generation of an NO_x-containing gas by one of the NO_x generation steps allocated to the reducing agent generating unit from the air and/or exhaust gas supplied to the generation step;

b) Intermediate storage of NO_x during the passage of the NO_x-containing gas produced during operation a by an NO_x intermediate storage allocated downstream to the NO_x generation step, and arranged to the reducing agent-generating unit;

[0021] c) Generation of an H_2-containing gas by an H_2 generation step allocated to the reducing agent-generating unit and arranged upstream from the NO_x intermediate storage unit from fuel, as well as air and/or exhaust gas supplied to the H_2 generation step;

[0022] d) Reaction of NO_x stored in the NO_x intermediate storage unit with the gas produced in generation step cc into NH_3, so that an H_2-containing, and an NH_3-containing reducing gas is produced, whereby the operations a, and b are alternately performed with operations c and d.

[0023] With process control according the invention, the NO_x generation and NO_x intermediate storage unit takes place alternately with the generation of an H_2-containing, reducing gas, release of the intermediately stored NO_x and its reduction to NH_3. An H_2/NH_3-containing reduction gas is added intermittently to the reducing catalytic converter. Since, however, preferably an NH_3 storing SCR catalytic converter is employed as NO_x reducing catalytic converter, this can nevertheless continuously reduce NO_x contained in exhaust gas, since in the operating phases, in which no NH_3 is added to the catalytic converter, NH_3 added in the preceding operating phase and stored is used for NO_x reduction. By the NO_x intermediate storage unit in the operating phases of the NO_x generation, an enrichment of the produced NO_x takes place, which when reducing gas with reducing composition is added, is released again in higher concentration from the NO_x intermediate storage unit, and turned into NH_3. Therefore, the reducing agent NH_3 can be added to the NO_x reducing catalytic converter at a comparatively high concentration.

[0024] In refinement of the procedure the NO_x reaction into NH_3 takes place in an NH_3 generation step, which is arranged to the reducing agent-generating unit, and arranged downstream to the NO_x intermediate storage unit. Preferably the NH_3 generation step contains an NH_3 formation catalytic converter which catalyzes the reductive reaction of NO_x into NH_3. A catalytic converter with a very high efficiency with respect to NH_3 formation is for example described in the unpublished German patent application 10214686.1. If NO_x and H_2-containing reducing gas is added to such a catalytic converter, a reaction results from NO_x to NH_3 from a high percentage.

[0025] In a further refinement of the procedure, the intermediate storage of NO_x, and the NO_x reaction to NH_3 is performed by means of a catalytic NO_x intermediate storage. The catalytic NO_x intermediate storage preferably has an NH_3 formation function in such a way that stored NO_x is reduced to NH_3 at least partially under reducing, or stoichiometrical conditions. Such a behavior is shown for example by NO_x storage catalytic converters, which are preferably employed here. By the functions of the NO_x intermediate storage, and the NH_3 formation integrated into a catalytic component, a compact construction of the reducing agent-generating unit can be achieved.

[0026] A further procedure according to the invention is characterized by the following operations:

a) Generation of an NO_x-containing gas of an NO_x generation step allocated to the reducing agent-generating unit, from air and/or exhaust supplied to the NO_x generation step;

[0027] b) Generation of an H_2-containing and NH_3-containing reducing gas by an H_2 generation step, allocated to the reducing agent-generating unit and arranged downstream from the NO_x generation step, from the NO_X-containing gas supplied to the H_2 generation step, fuel supplied, as well as air supplied and/or exhaust gas supplied.

[0028] By means of this process control in accordance with the invention, a continuous generation of an H_2-containing and NH_3-containing reducing gas, and its supply to the NO_x reducing catalytic converter takes place. Preferably, the H_2 generation step has a catalytic converter with NH_3 formation function, and by the H_2 generation step an H_2-containing and NH_3-containing reducing gas is produced. The H_2 elimination reaction from the HC-containing fuel in the H_2 generation step, and the reduction of the added NO_x to NH_3 is performed in the same procedure. Thus an H_2 and NH_3-containing reducing gas is generated in one operation. This advantageously simplifies the realization of the reducing agent-generating unit.

[0029] In refinement of the procedures according to the invention in one of the fractioning units arranged to the reducing agent generation unit, a fuel enriched in low-boiling components is produced, which is added to the reducing agent generation unit for the generation of reducing gas. The H_2 generation step is thereby supplied with low-molecular hydrocarbons, whereby its educt gas stream is better homogenized, a change into coke is prevented, and the H_2 yield is increased.

[0030] In refinement of the procedures according to the invention the NO_x reducing catalytic converter is divided into a denox catalytic converter step for the reaction of NO_x with H_2, and into an SCR catalytic converter step for the reaction of NO_x with NH_3, and depending upon its composition, the reducing gas is supplied to the exhaust gas on the input side to the SCR catalytic converter step (**3***a*), or on the input side to the denox catalytic converter step (**3***b*). Since the catalytic converter steps have different temperature ranges for their effectiveness, and the HC, H_2, NH_3 generated by the reducing agent-generating unit have their optimal effectiveness at various temperatures, a high NO_x reduction in exhaust gas can thereby be achieved in a broad temperature range. The denox catalytic converter step may also be designed for the reduction of NO_x with HC, which expands the application area of the reducing gas.

[0031] In further refinement of the procedure, the amount and/or the composition of the reducing gas generated by the reducing gas generation unit is set as a function of the operating state of the internal combustion engine. Preferably, the reducing agent generation unit provides more reducing gas at high-volume NO_x emissions of the internal combustion engine than at low. The procedure is preferably controlled in such a way that the effect of the relevant NO_x reducing catalytic converter brings the optimal benefit. At low charge of the internal combustion engine, or low exhaust gas temperature, preferably a reducing gas rich in H_2 is produced. At a higher load of the internal combustion engine, or a higher exhaust gas temperature, the reducing agent-generating unit is preferably operated in such a way that the reducing gas contains more NH_3. Thereby in turn an SCR catalytic converter with higher NO_x conversion is operated in the exhaust gas train of the internal combustion engine.

BRIEF DESCRIPTION OF THE DRAWINGS

[0032] The invention is explained below in greater detail on the basis of drawings and related examples.

[0033] **FIG. 1** is a schematic block diagram of an internal combustion engine with reducing agent-generating unit;

[0034] **FIG. 2** is a schematic block diagram of a construction of a reducing agent-generating unit;

[0035] **FIG. 3** is a schematic block diagram of the construction of a further embodiment of the reducing agent-generating unit;

[0036] **FIG. 4** is a schematic block diagram of the construction of a further embodiment of the reducing agent-generating unit;

[0037] **FIG. 5** is a schematic block diagram of the construction of a further embodiment of the reducing agent-generating unit; and

[0038] **FIG. 6** is a schematic block diagram of the construction of an embodiment of the reducing agent-generating unit with an allocated fractioning unit.

DETAILED DESCRIPTION OF THE INVENTION

[0039] **FIG. 1**, an internal combustion engine **1** realized as a four-cylinder Diesel engine is shown here by way of example. In the following, simply the term motor will be used. The exhaust gas produced in the combustion process is conducted to the environment via the exhaust gas line **2**. In exhaust gas line **2** here, by way of example the catalytic converter steps **3**a, and **3**b comprising the NO_x reducing catalytic converter **3** is arranged.

[**0040**] The catalytic converter step **3**a is realized as SCR catalytic converter, by means of which with NH_3 as reducing agent an NO_x reduction takes place under lean exhaust gas conditions. An SCR catalytic converter on a $V_2O_5/WO_3/TiO_2$ basis as full extrudate, or another catalytic converter suitable for the NO_x reduction with NH_3 may be employed. The temperature range of the effectiveness of the catalytic converter step **3**a normally is in the range between 200° C. and 400° C.

[**0041**] The catalytic converter step **3**b is realized as denox catalytic converter, by means of which an NO_x reduction takes place under lean exhaust gas conditions with H_2 and/or HC as a reducing agent. Preferably a precious metal-containing catalytic converter is employed, but a Cu substituted zeolite, or another catalytic converter suitable for the NO_x reduction with H_2 or HC may also be employed. The temperature range of the effectiveness of the catalytic converter step **3**b, with H_2 as reducing agent, normally is in the range between 80° C. and 200° C., with HC as reducing agent between 180° C. and 400° C.

[**0042**] The reducing agent-generating unit **20** serves for the generation of the reducing agent H_2 and/or NH_3. For this purpose, it may be supplied with fuel, or air, or exhaust gas via the fuel supply line **9**, or via the gas supply line **10** as needed. The reducing agent-generating unit **20** has a controlled heating system (not shown), which is mainly operated for start-up. The reducing gas produced by the reducing agent-generating unit **20**, may be added to the exhaust gas on the input side of the catalytic converter steps **3**a, **3**b, via the addition line **8**, and the addition locations **4**, **5**.

[**0043**] The operation of the motor, and the operation of the reducing agent-generating unit **20** is controlled by a motor control unit **6**, which, for this purpose is connected with the motor **1**, or with the reducing agent-generating unit **20** via control lines **7**.

[**0044**] Of course, additional components may be arranged to the motor **1**, or the exhaust gas system, which are not shown here for reasons of clear grouping. These may especially consist of further catalytic pollution abatement units, a particle filter, and sensors in the exhaust gas line **2**, as well as the usual additional motor components such as injection system, exhaust gas turbocharger, components for the exhaust gas return, etc. Also not shown are switchable, or adjustable locking mechanisms in the addition line **8**, and the addition lines **9**, **10**.

[**0045**] The reducing agent unit **20** is now operated in such a way that reducing gas is produced as a function of the NO_x emission of the motor **1**, and is added to the exhaust gas on the input side of the catalytic converter steps/step **3**a and/or **3**b. For this, in the motor control unit **6**, there exist, for example, performance characteristics, in which the NO_x emission is laid down as a function of the motor operating point. The procedure of the reducing gas generation is controlled and monitored by the motor control unit **6**, whereby the motor control unit **6** has all the necessary information available regarding the reducing gas composition, and the operating status of the reducing agent-generating unit **20**.

[**0046**] The motor control unit **6** controls the addition amounts of air, or exhaust gas, as well as fuel, and the operation of the reducing agent-generating unit **20** preferably in such a way, that with a low exhaust gas temperature, reducing gas is mainly supplied to the exhaust gas via the addition location **4** at the inlet of the denox catalytic converter **3**b. The reducing gas generation is hereby controlled in such a way, that the reducing gas predominantly contains H_2 as reducing agent. Thereby, also at low exhaust gas temperatures, or at low temperatures of the catalytic converter step **3**b, an efficient NO_x reduction of the motor exhaust gas is achieved. The addition amount of the reducing gas thereby is set by the motor control unit **6** according to the NO_x contents of the exhaust gas of the exhaust gas temperature, or the temperature of the catalytic converter step **3**b, as well as the H_2 contents of the reducing gas. Preferably a molar ratio of about 3:1 of H_2:NO_x is set at the input side of the denox catalytic converter.

[**0047**] If, with increasing exhaust gas temperature, the catalytic converter step **3**b falls outside of the temperature range of its efficiency, the addition amount of predominantly H_2-containing reducing gas is reduced, or stopped at the addition location **4**. At the same time, the operation at the reducing agent-generating unit is changed in such a way that this results in a higher NH_3 portion, and the reducing gas is added to the exhaust gas at addition location **5** at the input of catalytic converter step **3**a. Since with increasing exhaust gas temperature the SCR catalytic converter of the catalytic converter step **3**a becomes gradually more efficient, now the NO_x reduction takes place predominantly at this catalytic converter.

[**0048**] At a further continuous increase of the exhaust gas temperature, also the SCR catalytic converter of the catalytic converter step **3**a may come outside of the temperature range of its effectiveness. In this case, the reducing gas generation is changed in such a way that mainly a cracked fuel with short-chain hydrocarbons is produced from the reducing agent-generating unit **20**. This reducing gas may then be conducted to the further downstream located, and therefore less hot, denox catalytic converter of catalytic converter step **3**b. At this catalytic converter, at temperatures of about 300° C., an NO_x reduction with these hydrocarbons takes place.

[**0049**] Further catalytic converters, which are not shown here, may be arranged in the exhaust gas line **2**, which can also be supplied with reducing gas, as needed, via an appropriate addition location. In particular, H_2-containing reducing gas may be apportioned to the exhaust gas at the inlet of a primary catalytic converter arranged near the motor for reducing emissions during a cold start of the motor **1**. A rapid heating of the primary catalytic converter can be achieved in this way. As a consequence, pollutants can be removed from the exhaust gas already in an early phase of the motor warm-up period.

[**0050**] **FIG. 2** schematically shows the construction of the reducing agent-generating unit **20** in a preferred embodiment. The reducing agent-generating unit **20** here comprises an H_2 generation step **21**, an NO_x generation step **22**, an NO_x intermediate storage unit **23**, and an NH_3 generation step **24** in serial arrangement. The H_2 generation step **21** can be supplied with fuel at measured volumes via the fuel supply line **9**, and air, and/or exhaust gas via the gas supply line **10**. The NO_x generation step **22** can also be supplied with air, and/or exhaust gas at measured volumes via the gas supply line **10**. The means used for measuring the volume are not shown here.

[**0051**] The embodiment of the reducing agent-generating unit **20** represented is preferably operated alternately, so that alternately NH_3 and/or H_2, or NO_x are being produced. For producing H_2, the H_2 generation step **21** realized as a catalytic POX reactor, if needed, is first of all warmed-up to operating temperature by means of a not shown electric heater. Hereby, the operating temperature of the catalytic converter arranged in the POX reactor is about 600° C. to 1000° C. Afterwards, the POX reactor is supplied with fuel, and air, or exhaust gas in a weighted flow determined by the motor control unit. Thereby, a air/fuel ratio of preferably about $\lambda=0.3$ is set. At this lambda value the partial fuel oxidation in the POX reactor is practically free of soot. The reaction product consists of a reducing gas with a composition, which is highly dependent on the course of procedure, i.e. mainly on the temperature of the POX catalytic converters, and on the air/fuel ratio set. Typical content levels of the reducing agent H_2 or CO are about 18%. The reducing gas may additionally contain a certain content of low-molecular hydrocarbons.

[**0052**] This reducing gas is now conducted through the NO_x generation step **22**, which is not in operation during this phase of the reducing gas generation. After passing it through the NO_x generation step **22**, the reducing gas flows through the NO_x intermediate storage unit **23**, which contains an NO_x adsorber. The NO_x adsorber may for example be a ceramic honeycomb body, which is coated with a material, which in oxidizing conditions absorbs NO_x by adsorption, or absorption, and which releases NO_x again in reducing conditions. For this, an NO_x adsorber material on a silver basis is suitable, for example. If the NO_x intermediate storage unit was loaded with NO_x before the reducing gas produced in the H_2 generation step **21** flows through, it is consequently released. The reducing gas enriched with NO_x is further conducted to the NH_3 generation step **24**. This preferably contains a catalytic converter with a precious metal coating. The reduction of NO_x to NH_3 is catalyzed by this catalytic converter, so that finally an NH_3 and H_2-containing reducing gas leaves the reducing agent-generating unit **20** via the reducing gas line **8**, and is added at one, or both of the addition locations **4**, **5** to the exhaust gas of the motor **1** (see **FIG. 1**).

[**0053**] If the NH_3 formation comes to a halt, for example by exhaustion of the amount of NO_x stored in the NO_x intermediate storage unit, if needed, the operation of the reducing agent-generating unit **20** for producing NO_x can be switched. For this purpose, the supply of air, or exhaust gas, as well as the supply with fuel to the H_2 generation step **21** is stopped. Subsequently, the NO_x generation step **22** is supplied with air and/or oxygen-containing exhaust gas. In the NO_x generation step **22** thereupon for example a plasma process is started, or an electric arc, or a corona discharge is ignited. By such a process NO_x is produced in the nitrogen and oxygen-containing atmosphere of the NO_x generation unit. Preferably an NTP procedure (NTP=non-thermal plasma) is started, and maintained for the desired time of the NO_x generation. The NO_x produced by means of this process has a high NO_2 portion of normally over 50%, which improves the subsequent storage after the supply of the generation gas to the NO_x intermediate storage unit **23**. As described above, in this situation the supplied NO_x is to be absorbed by adsorption, or by absorption. The NO_x free gas is further conducted through the NH_3 generation step, from where it is added essentially unchanged to the exhaust gas of the motor **1** via the reducing gas line **8** at one of the addition locations **4**, **5** (see **FIG. 1**). If the NO_x intermediate storage unit **23** is saturated with NO_x, or if the supply of reducing gas to a catalytic converter step is required for other reasons, the generation of NO_x is stopped, and the generation of reducing gas with a reducing effect as described above again takes place.

[**0054**] **FIG. 3** schematically illustrates the construction of the reducing agent-generating unit **20** in a further preferred embodiment. The designation and the function of the of the components with the same effectiveness, corresponds to **FIG. 2**. As compared to the embodiment shown in **FIG. 2**, the reducing agent-generating unit **20** shown in **FIG. 3** differs in the exchange of the H_2 generation step **21**, and the NO_x generation step **22**. Also the embodiment of the reducing agent-generating unit shown in **FIG. 3** is preferably operated alternately such, that alternately H_2 and/or NH_3 are produced, or NO_x is produced. In the operating phases with NO_x generation, however, in turn the H_2 generation step **21** is not in operation, and the NO_x-containing product gas of the NO_x generation step **22** flows through the H_2 generation step **21**. Thereby, in the warmed-up H_2 generation step **21** a regeneration of coking possibly caused by the cracking process may occur, which improves the operatability of the POX catalytic converter. Analogous to the function of the embodiment shown in **FIG. 2**, NO_x is withdrawn from the gas in the NO_x intermediate storage unit **23** by storage. After switching the operation of the reducing agent-generating unit **20** by terminating the NO_x generation, and starting operation of the H_2 generation step **21**, reducing H_2-containing reducing gas flows through the NO_x intermediate storage unit **23**, whereby the release of the stored NO_x takes place, as described above. In the downstream arranged NH_3 generation step **24** thereupon a reaction of the stored NO_x into NH_3 takes place, and the reducing gas is enriched with NH_3. The produced reducing gas is, as described above, fed as needed at the inlet of a catalytic converter step into the exhaust gas line.

[**0055**] **FIG. 4** schematically shows the construction of a reducing agent-generating unit **20** in a further preferred embodiment. Analogous to the embodiments in **FIG. 2**, and **FIG. 3**, this variation is also operated alternately. The differences in construction and in their function as compared to the embodiments in **FIGS. 2 and 3** are described in the following. To the NO_x generation step **22**, here an NO_x storage catalytic converter step **26** is arranged downstream, which at the same time fulfills the function of the NO_x intermediate storage unit and the NH_3 formation. In the supply of reducing reducing gas from the H_2 generation step **21** to the NO_x storage catalytic converter step **26**, the NO_x which is stored there gets released and at the same time NH_3 gets reduced. This effect, which occurs in the usual NO_x storage catalytic converters, can be utilized advantageously. Preferably in this step **26** an NO_x storage material is employed, which, with respect to the NH_3 formation is for example optimized by an increased rhodium content. A further simplification is achieved in that the gas necessary for the generation of NO_x is supplied to the NO_x generation step **22** via the H_2 generation step **21**; therefore a branching of the gas supply line **10** can be eliminated. In comparison to the embodiments in **FIG. 2** and **FIG. 3** components can be eliminated hereby, whereby the reducing agent-generating unit **20** can be realized in a simpler way.

[0056] **FIG. 5** schematically shows the construction of the reducing agent-generating unit **20** in a further preferred embodiment. As explained in the following, this embodiment can be operated on a continuous basis, i.e. the NO_x generation and NH_3 generation can take place simultaneously. For this purpose a reactor step **25** is provided, in which simultaneously an H_2 generation, preferably by a catalytic partial oxidation process, and a reduction of the NO_x supplied to the NO_x generation step **22**, can take place. The NO_x generation thereby is performed as described in the above embodiments. The necessary educt gas is supplied to the NO_x generation step **22** via the gas supply line **10** as needed. The gas supply line additionally may have a branch for reactor step **25**. The reactor step **25** is supplied with hydrocarbon-containing fuel via the supply line **9**. Preferably in the operation of reactor step **25** an air/fuel ratio of about $\lambda=0.3$ is set there. In this way, the thermodynamically preferred conditions are present, on the one hand for the H_2 generation by partial oxidation, and on the other hand for the reduction of NO_x to NH_3, so that H_2 as well as NH_3 can be produced in one process. The volume ratio of these two components thereby can be set as needed by the appropriate setting of fuel, or NO_x supplied to reactor step **25**.

[0057] **FIG. 6** schematically shows the construction of the reducing agent-generating unit **20** in a further preferred embodiment. The reducing agent-generating unit **20** contains, analogous to the embodiment shown in **FIG. 4**, an H_2 generation step **21** arranged downstream to the NO_x generation step **22**. The furthermore downstream arranged NO_x storage catalytic converter step **26** serves for the NO_x intermediate storage and NH_3 generation. The system is preferably operated in altering generation phases, and H_2, or NH_3 generation phases. For the generation of NO_x, the NO_x generation **22** is supplied with air and/or exhaust gas via the gas supply line **10**. Via a branch-off, the H_2 generation step **21** can be supplied with air and/or exhaust gas as well. To the reducing agent-generating unit **20** furthermore a fractioning unit **27** is arranged to, in which from the fuel provided for the motor operation, low-boiling components are separated off in a fractioning process. For this purpose the fractioning unit **27** is supplied with fuel from the storage container of a motor not shown here, via the fuel supply line **9**. Via the return line **9***b* the fuel enriched in low-boiling components is returned again. The separated low-boiling fuel components are conducted to the H_2 generation step **21** for H_2 generation via the fuel supply line **9***a*. By the fact, that the H_2 generation step **21** is operated with low-boiling hydrocarbons, the H_2 generation can take place with a higher yield, and the danger of coking of the POX catalytic converter is reduced. In addition, the possibility exists for preparing the low-boiling fuel components when needed only at low levels, and to add to the lean exhaust gas on the input side of a denox catalytic converter. Therefore, in the temperature range of about 200° C. to 350° C. an efficient NO_x reduction may be achieved. To increase the H_2 yield in the generation of reducing gas, the reducing agent-generating unit **20** can generally be supplied with additional water. The water can thereby be taken from a storage container of the associated motor vehicle, or be obtained by condensation from the motor exhaust gas. The water may, for example be utilized for a steam reforming process in the H_2 generation step **21**. Apart from the increase of the H_2 content in the produced reducing gas this brings the additional advantage, that this endothermal process improves the heat and energy balance of the H_2 generation. Furthermore a larger range for temperature management in the H_2 generation step **21**, and the complete reducing agent-generating unit **20** is gained. The water may, however, also be supplied to a water gas shift step arranged downstream from the H_2 generation step **21**. The thereby with H_2 enriched reducing gas has a higher selectivity in the NH_3 generation, and in the NO_x reduction at a denox catalytic converter. At the same time the CO contents is reduced in the reducing gas, which prevents a poisoning of the denox catalytic converter by CO accumulation of active catalytic centers.

[0058] It is obvious that to the reducing agent-generating unit **20** heat exchangers may be arranged to, in order to improve the heat and energy balance of the total process, and the course of the procedure. Thus, for preheating of the supplied air, or the supplied exhaust gas for example, a heat exchanger may be provided in the gas supply line **10**. Heat exchangers may, however, also be provided in the reducing agent-generating unit **20**, for example in order to utilize the heat content of the hot product gas flow of the H_2 generation step, or the NH_3 generation step for preheating of the educt gas of a preliminary step.

1-18. (canceled)

19. An internal combustion engine comprising:

an exhaust gas line in which an NO_x reduction catalytic converter is arranged, and

a reducing agent-generating unit for generation of H_2-containing and NH_3-containing reducing gas which can be added upstream of the NO_x reduction catalytic converter in the exhaust gas line,

wherein the reducing agent-generating unit can be supplied with at least one of an HC-containing fuel, air, and exhaust gas, and

wherein the reducing agent-generating unit has an NO_x generation step and an H_2 generation step in serial arrangement.

20. The internal combustion engine according to claim 19, wherein the NO_x generation step is arranged downstream from the H_2 generation step.

21. The internal combustion engine according to claim 19, wherein the NO_x generation step is arranged upstream from the H_2 generation step.

22. The internal combustion engine according to claim 19, further comprising an NH_3 generation step arranged downstream from the NO_X generation step.

23. The internal combustion engine according to claim 20, further comprising an NH_3 generation step arranged downstream from the NO_X generation step.

24. The internal combustion engine according to claim 21, further comprising an NH_3 generation step arranged downstream from the NO_X generation step.

25. The internal combustion engine according to claim 19, wherein the reducing agent-generating unit can be operated alternately in first and second operating modes in such a way that, during the first operating mode, an NO_X-containing gas can be produced and, during the second operating mode, an H_2-containing and NH_3-containing reducing gas can be produced.

26. The internal combustion engine according to claim 22, wherein a reducing agent-generating unit can be operated alternately in first and second operating modes in such a way that, in the first operating mode, an NO_X-containing gas can be produced and, in the second operating mode, an H_2-containing and NH_3-containing reducing gas can be produced.

27. The internal combustion engine according to claim 23, wherein a reducing agent-generating unit can be operated alternately in first and second operating modes in such a way that, in the first operating mode, an NO_X-containing gas can be produced and, in the second operating mode, an H_2-containing and NH_3-containing reducing gas can be produced.

28. The internal combustion engine according to claim 24, wherein a reducing agent-generating unit can be operated alternately in first and second operating modes in such a way that in the first operating mode of the NO_X generation step, an NO_X-containing gas can be produced and, in the second operating mode, an H_2-containing and NH_3-containing reducing gas can be produced.

29. The internal combustion engine according to claim 25, further comprising an NO_X intermediate storage unit arranged downstream from the NO_X generation step.

30. The internal combustion engine according to claim 26, further comprising an NO_X intermediate storage unit arranged downstream from the NO_X generation step.

31. The internal combustion engine according to claim 27, further comprising an NO_X intermediate storage unit arranged downstream from the NO_X generation step.

32. The internal combustion engine according to claim 28, further comprising an NO_X intermediate storage unit arranged downstream from the NO_X generation step.

33. The internal combustion engine according to claim 29, wherein the NO_X intermediate storage unit is designed for reaction of stored NO_X with H_2 to NH_3.

34. The internal combustion engine according to claim 30, wherein the NO_X intermediate storage unit is designed for reaction of stored NO_X with H_2 to NH_3.

35. The internal combustion engine according to claim 31, wherein the NO_X intermediate storage unit is designed for reaction of stored NO_X with H_2 to NH_3.

36. The internal combustion engine according to claim 32, wherein the NO_X intermediate storage unit is designed for reaction of stored NO_X with H_2 to NH_3.

37. The internal combustion engine according to claim 21, wherein the H_2 generation step is designed for reaction of supplied NO_X into NH_3.

38. The internal combustion engine according to claim 24, wherein the H_2 generation step is designed for reaction of supplied NO_X into NH_3.

39. The internal combustion engine according to claim 28, wherein the H_2 generation step is designed for reaction of supplied NO_X into NH_3.

40. The internal combustion engine according claim 32, wherein the H_2 generation step is designed for reaction of supplied NO_X into NH_3.

41. The internal combustion engine according claim 36, wherein the H_2 generation step is designed for reaction of supplied NO_X into NH_3.

42. The internal combustion engine according to claim 19, wherein the engine is a Diesel engine.

43. A process for operation of an internal combustion engine having a reducing agent-generating unit and an exhaust gas line in which an NO_X reduction catalytic converter is arranged, whereby a reducing gas produced by the reducing agent-generating unit is added upstream of the NO_x reducing catalytic converter to the exhaust gas, wherein generation of the reducing gas comprises:

generating an NO_X-containing gas from an NO_X generation stage allocated to the reducing agent-generating unit from at least one of air and exhaust gas supplied to the NO_X generation stage; and

intermediately storing NO_X when conducting the NO_X-containing gas produced through an NO_X intermediate storage unit which is arranged downstream from the NO_x generation stage and allocated to the reducing agent-generating unit; or

generating an H_2-containing gas by an H_2 generation stage allocated to the reducing agent-generating unit and arranged upstream from an NO_X intermediate storage unit from fuel and air or exhaust gas supplied to the H_2 generation stage; and

reacting NO_X stored in the NO_X intermediate storage unit with the gas produced into NH_3 so that a reducing gas containing H_2 and NH_3 is produced.

44. The process according to claim 43, wherein reaction of NO_x into NH_3 takes place in the catalytic NH_3 generation stage, which is allocated to the reducing agent generation unit and arranged downstream from the NO_X intermediate storage unit.

45. The process according to claim 43, wherein intermediate storage of NO_X and reaction of NO_X into NH_3 is performed with a catalytic NO_X intermediate storage unit.

46. The process according to claim 43, wherein the NO_X reducing catalytic converter is divided into a denox catalytic converter stage for reaction of NO_X with H_2 and an SCR catalytic converter stage for reaction of NO_X with NH_3, and wherein the reducing gas is supplied to the exhaust gas as a function of its composition at an input side to the SCR catalytic converter stage or on an input side to the denox catalytic converter stage.

47. The process according to claim 44, wherein the NO_X reducing catalytic converter is divided into a denox catalytic converter stage for reaction of NO_X with H_2 and an SCR catalytic converter stage for reaction of NO_X with NH_3, and wherein the reducing gas is supplied to the exhaust gas as a function of its composition at an input side to the SCR catalytic converter stage or on an input side to the denox catalytic converter stage.

48. The process according to claim 45, wherein the NO_X reducing catalytic converter is divided into a denox catalytic converter stage for reaction of NO_X with H_2 and an SCR catalytic converter stage for reaction of NO_X with NH_3, and wherein the reducing gas is supplied to the exhaust gas as a function of its composition at an input side to the SCR catalytic converter stage or on an input side to the denox catalytic converter stage.

49. A process for operation of an internal combustion engine having a reducing agent-generating unit and an exhaust gas line in which an NO_X reduction catalytic converter is arranged, whereby a reducing gas produced by the reducing agent-generating unit is added upstream from the NO_x reducing catalytic converter to the exhaust gas, wherein generation of the reducing gas comprises:

generating an NO_X-containing gas from an NO_X generation stage allocated to the reducing agent-generating unit from at least one of air and exhaust gas supplied to the NO_X generation stage; and

generating an H_2-containing gas and an NH_3-containing reducing gas from an H_2 generation stage allocated to the reducing agent-generating unit and arranged downstream from the NO_X generation stage based on fuel fed to the H_2 generation stage, NO_X-containing gas produced, fuel supplied, and at least one of air and exhaust gas.

50. The process according to claim 49, wherein the NO_X reducing catalytic converter is divided into a denox catalytic converter stage for reaction of NO_X with H_2 and an SCR catalytic converter stage for reaction of NO_X with NH_3, and wherein the reducing gas is supplied to the exhaust gas as a function of its composition at an input side to the SCR catalytic converter stage or on an input side to the denox catalytic converter stage.

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