US 20080028757A1

(19) United States
(12) Patent Application Publication
Eitel et al.
(10) Pub. No.: US 2008/0028757 A1
(43) Pub. Date: Feb. 7, 2008

(54) **CONDENSER IN A TURBO-COMPRESSOR SYSTEM AND METHOD FOR OPERATING ONE SUCH SYSTEM**

(75) Inventors: **Jochen Eitel**, Bissingen (DE); **Gerhard Frankle**, Remshalden (DE); **Peter Geskes**, Ostfildern (DE); **Rainer Lutz**, Steinheim (DE); **Rolf Muller**, Ludwigsburg (DE); **Eberhard Pantow**, Moglingen (DE)

Correspondence Address:
FOLEY AND LARDNER LLP
SUITE 500
3000 K STREET NW
WASHINGTON, DC 20007 (US)

(73) Assignee: **BEHR GmbH & Co. KG**, Stuttgart (DE)

(21) Appl. No.: **11/577,616**

(22) PCT Filed: **Oct. 18, 2005**

(86) PCT No.: **PCT/EP05/11188**

§ 371(c)(1),
(2), (4) Date: **Jun. 25, 2007**

(30) **Foreign Application Priority Data**

Oct. 25, 2004 (DE) 10 2004 051 922.6
May 20, 2005 (DE) 10 2005 023 957.9

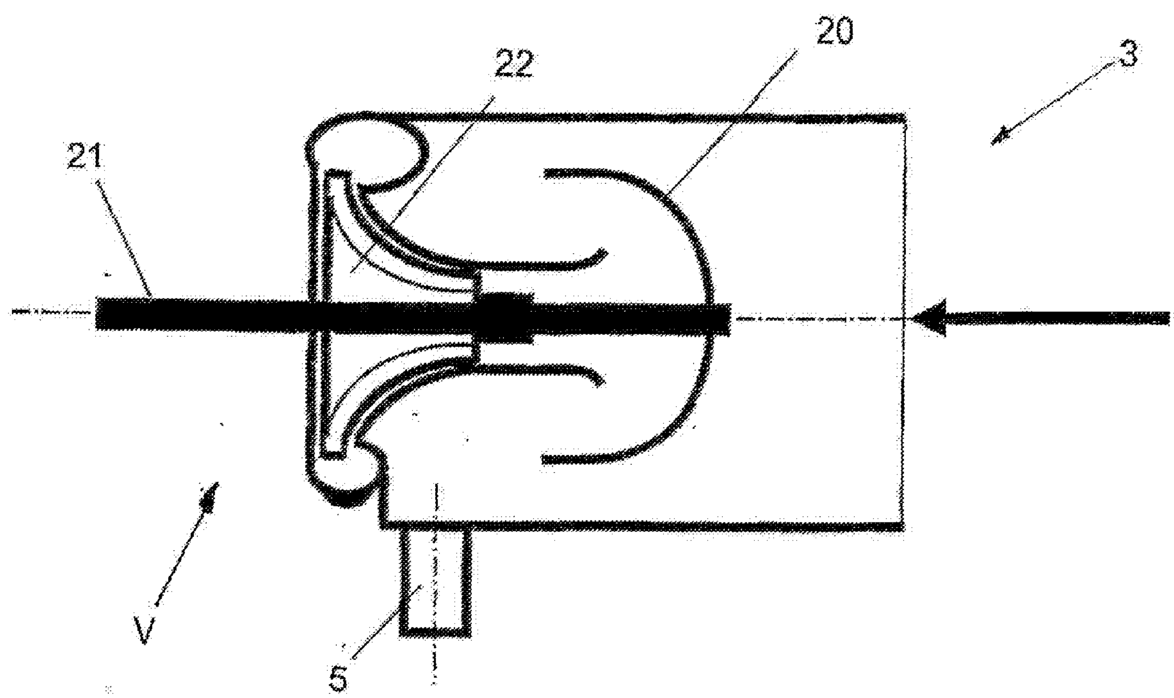
Publication Classification

(51) **Int. Cl.**
F01N 3/037 (2006.01)
F01N 3/00 (2006.01)
F01N 5/04 (2006.01)
F01N 3/04 (2006.01)
F01N 3/02 (2006.01)

(52) **U.S. Cl.** **60/311**; 60/274; 60/310; 60/280

(57) **ABSTRACT**

The invention relates to an system, especially a turbo-compressor system pertaining to a motor vehicle comprising an internal combustion engine with exhaust gas recirculation. Said system comprises an exhaust gas cooler (**2**) and a charge air cooler (**1**) for cooling recirculate exhaust gases and/or charge air, a compressor (V) for compressing the charge air, and at least on condenser (**3**).



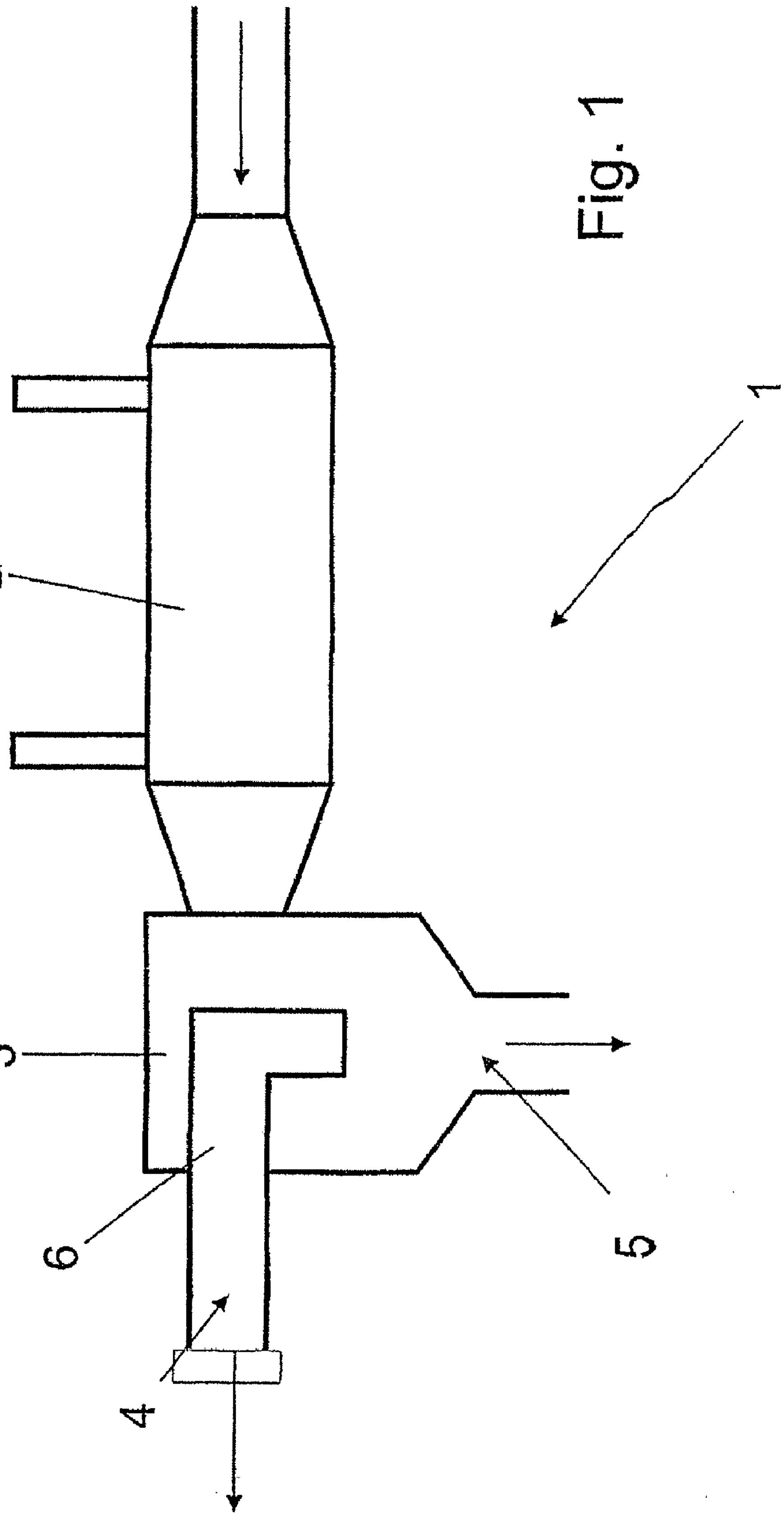


Fig. 1

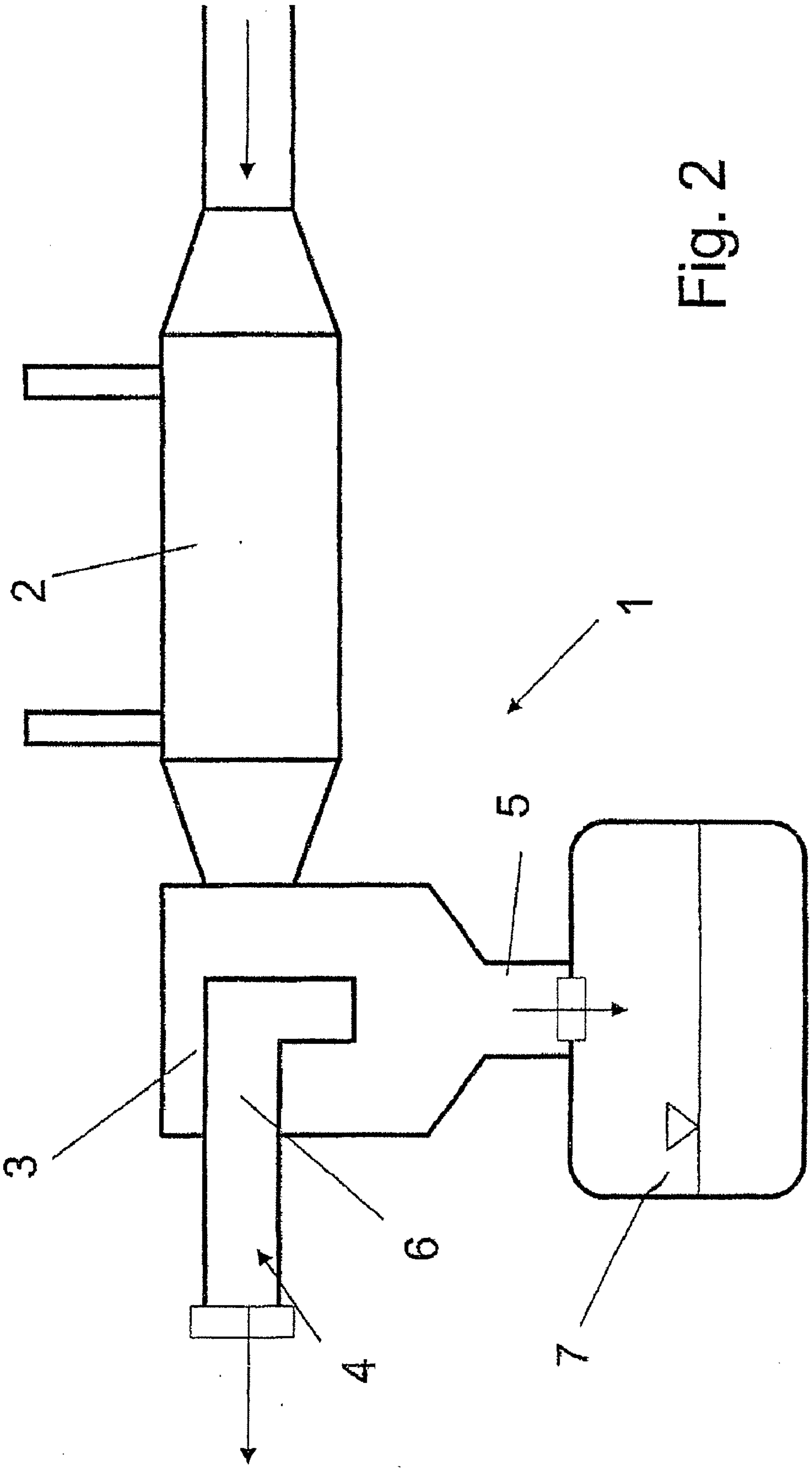


Fig. 2

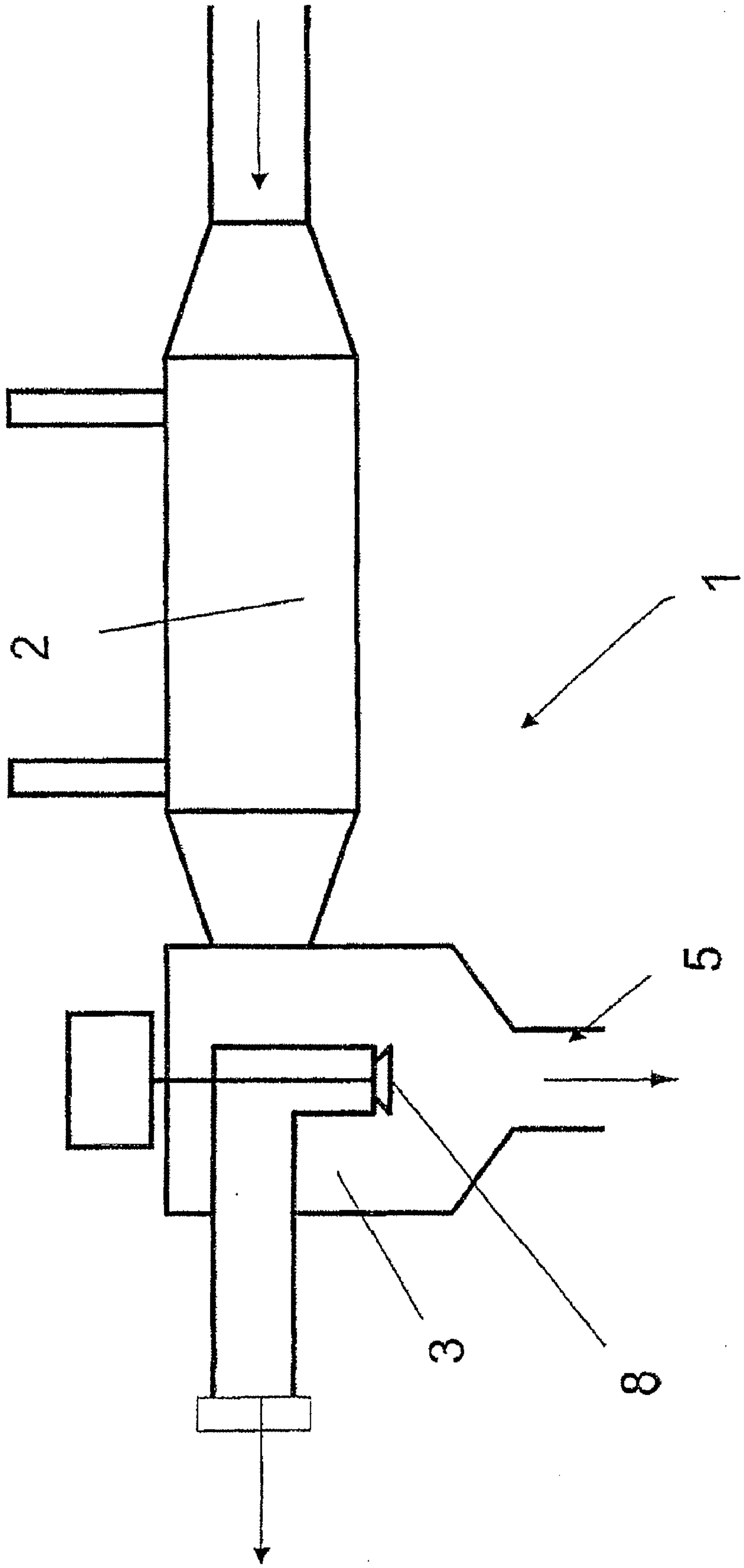


Fig. 3

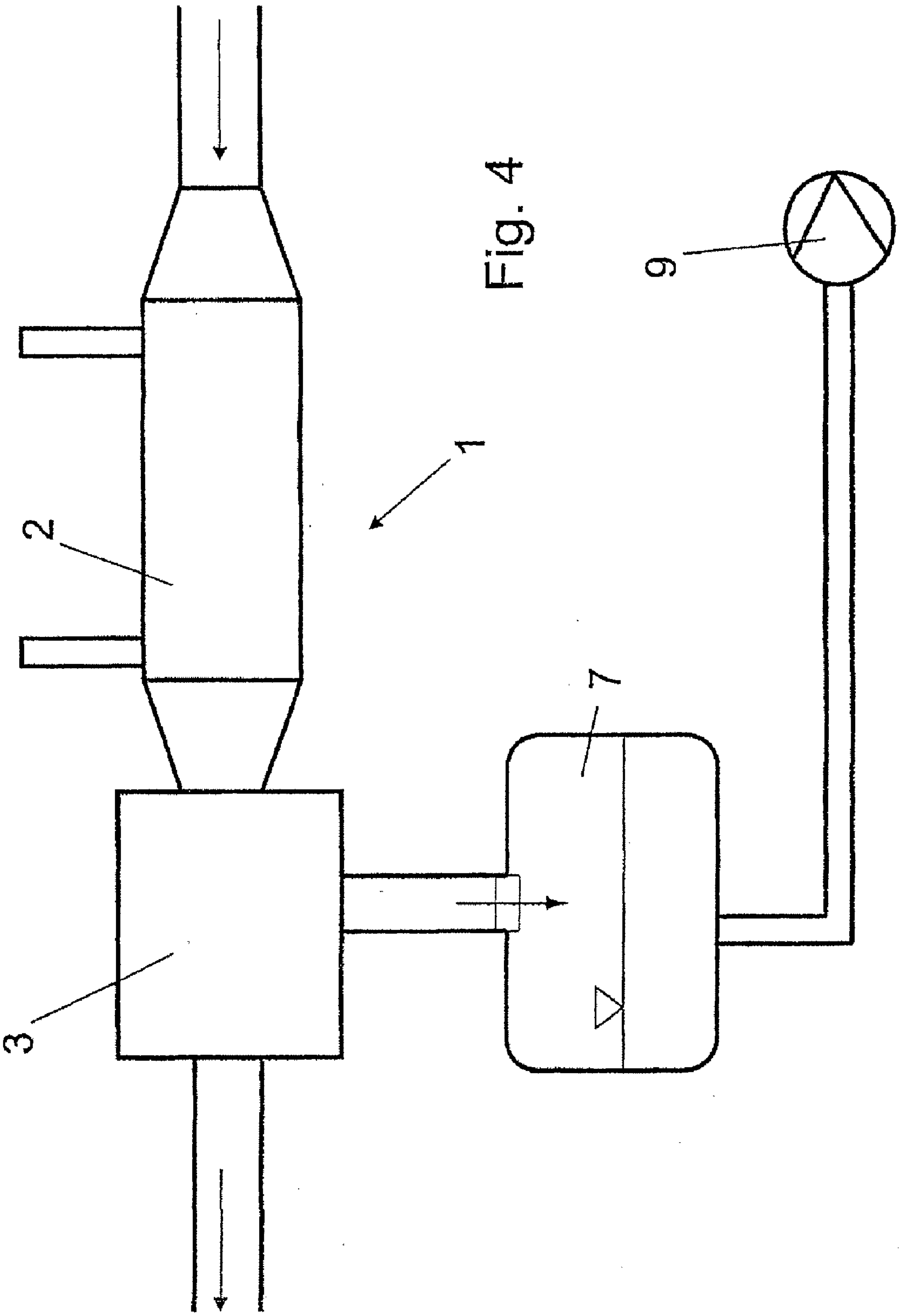


Fig. 4

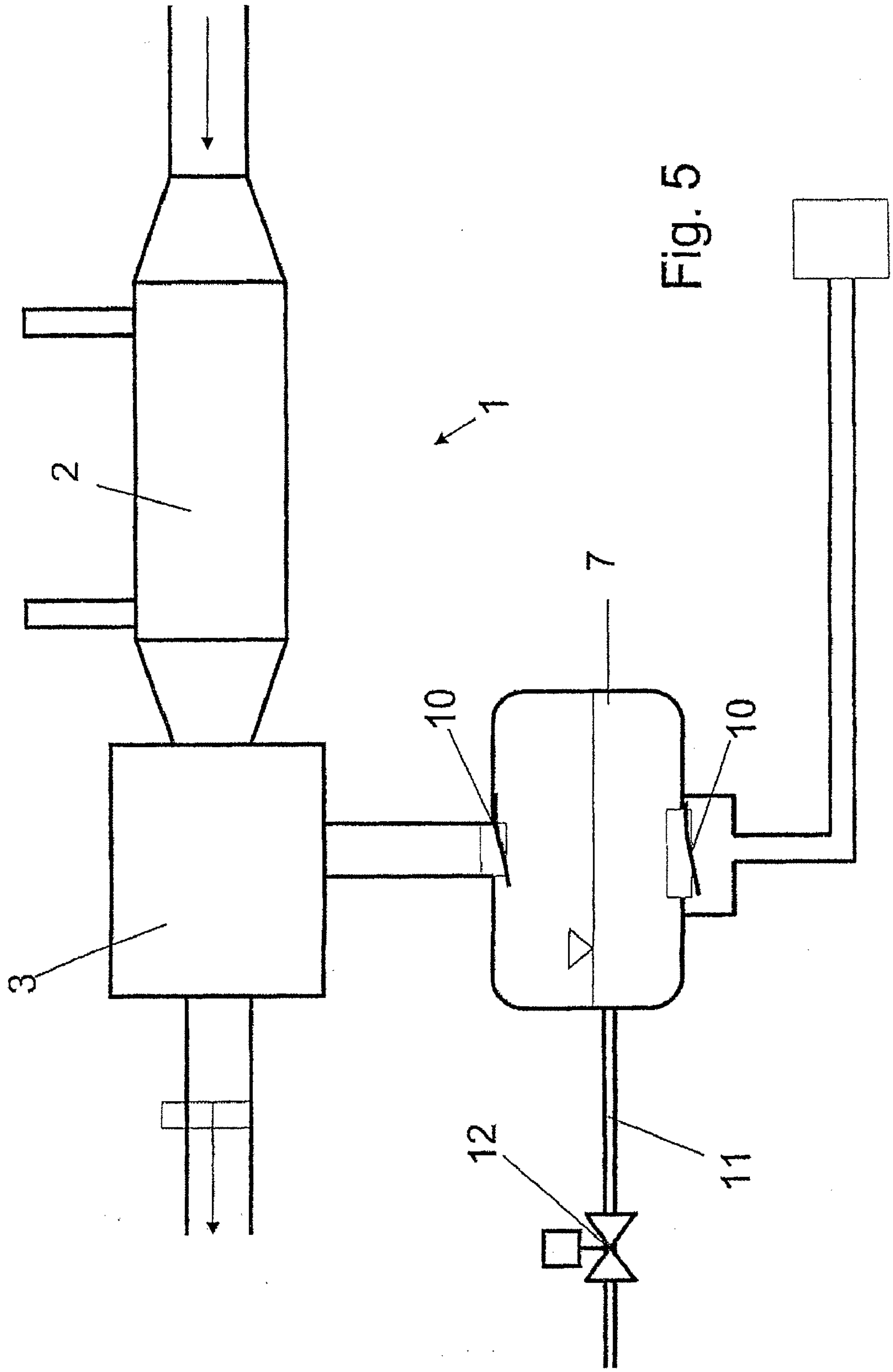


Fig. 5

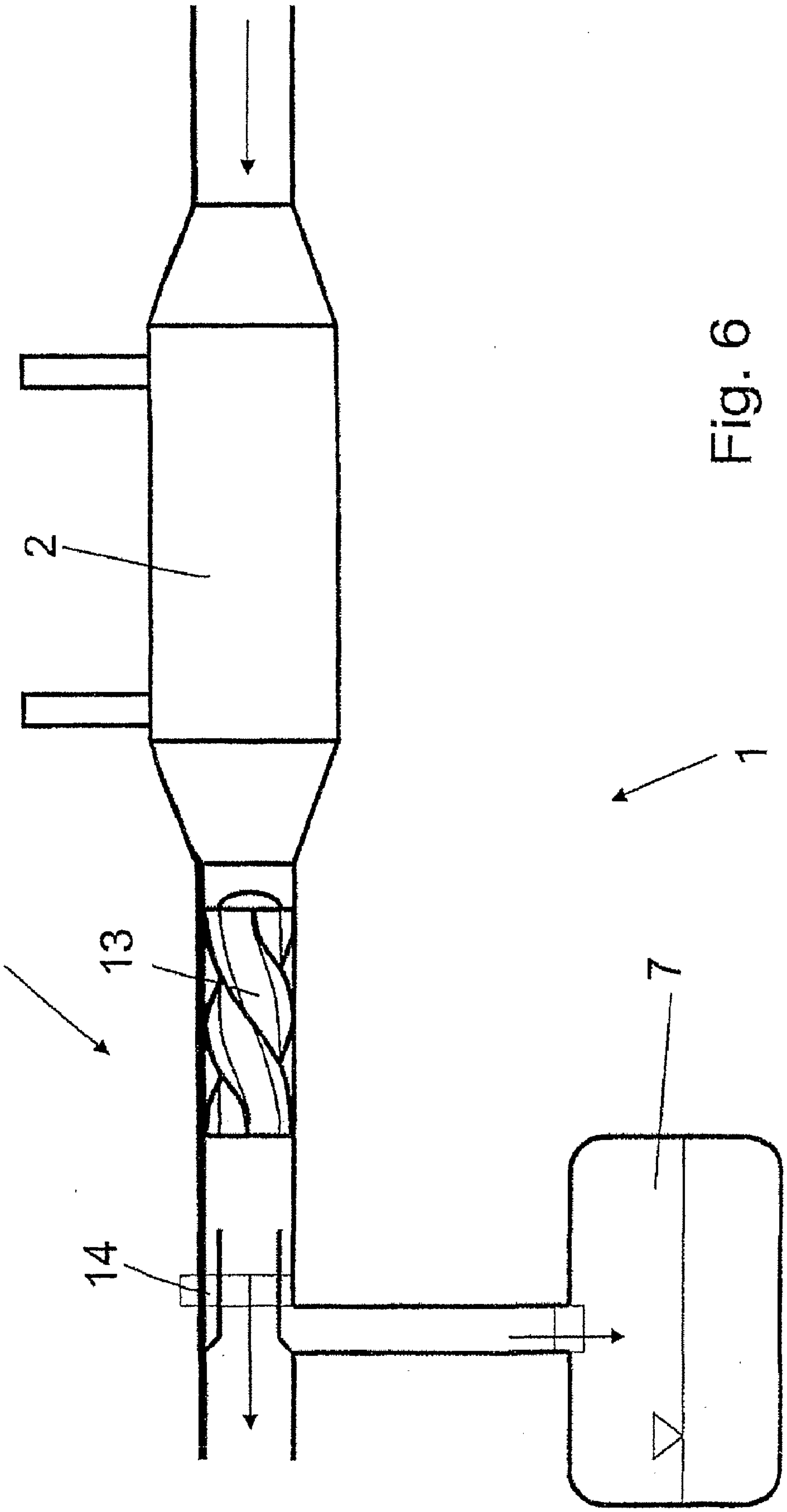


Fig. 6

Fig. 7

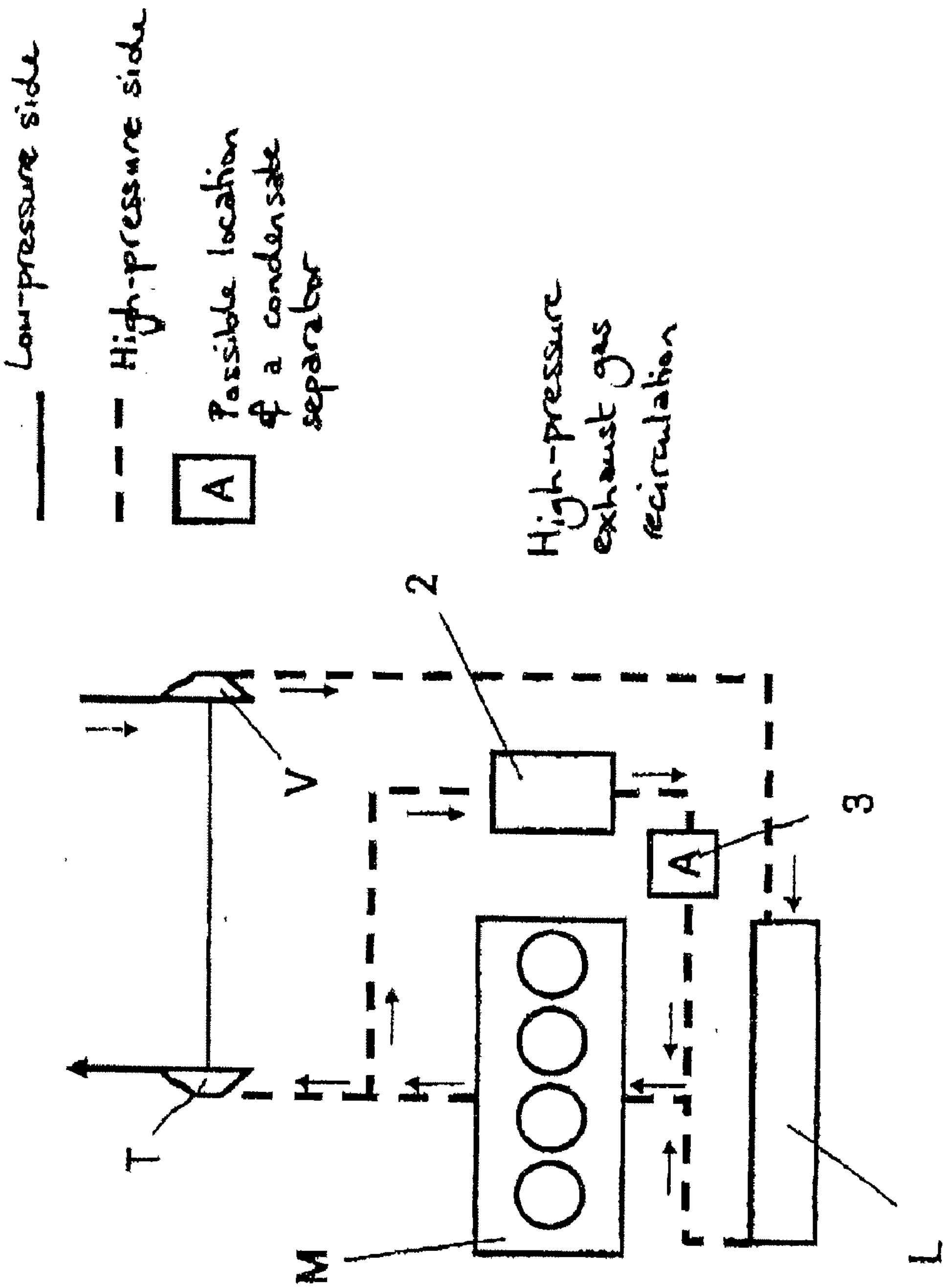
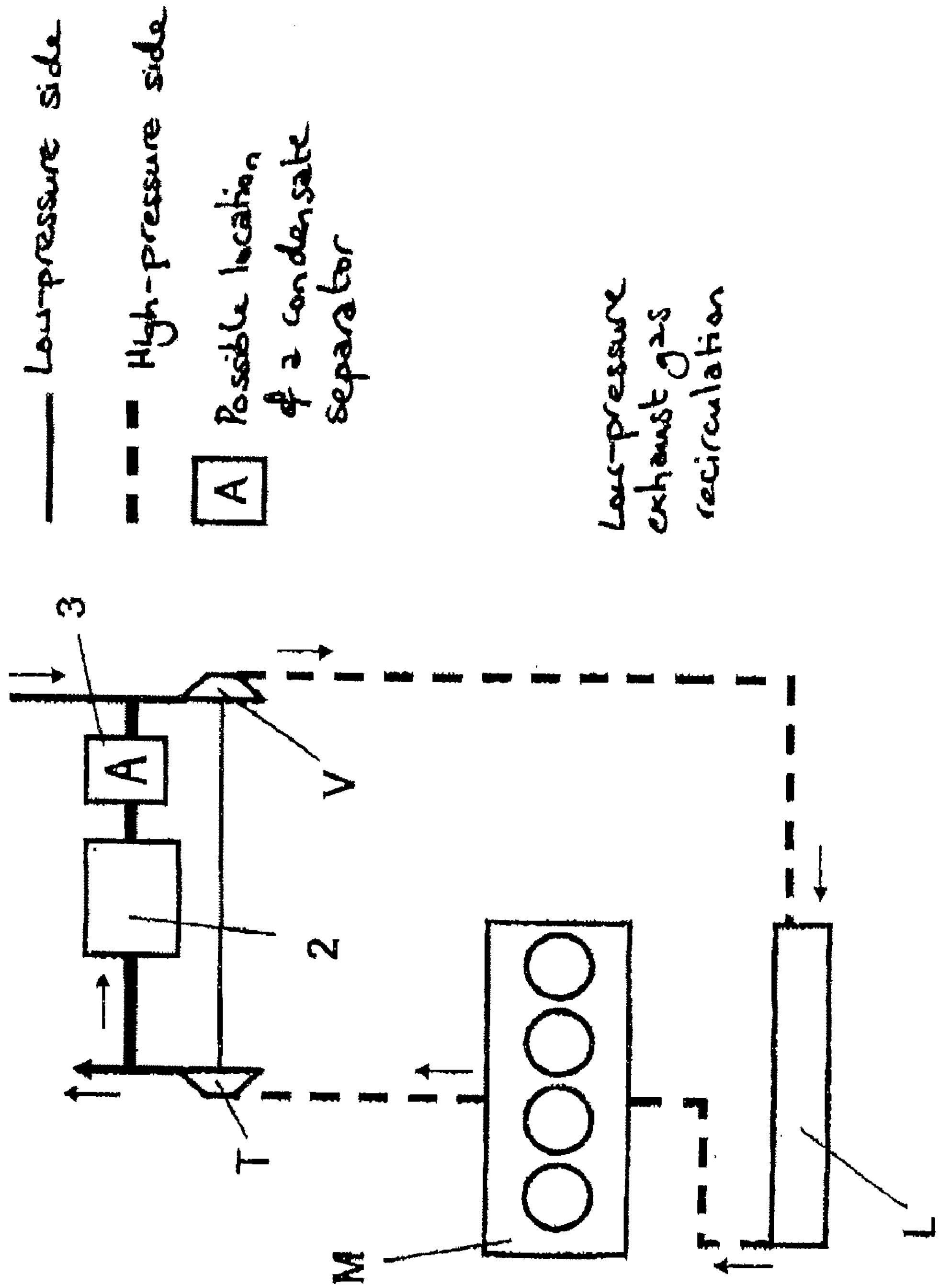

Low-pressure side
High-pressure side
A
Possible location of a condensate separator
High-pressure exhaust gas recirculation
2
V
3
A
T
M
L

Fig. 8


Low-pressure side
High-pressure side
A
Possible location of a condensate separator
Low-pressure exhaust gas recirculation
3
A
2
V
T
M
L

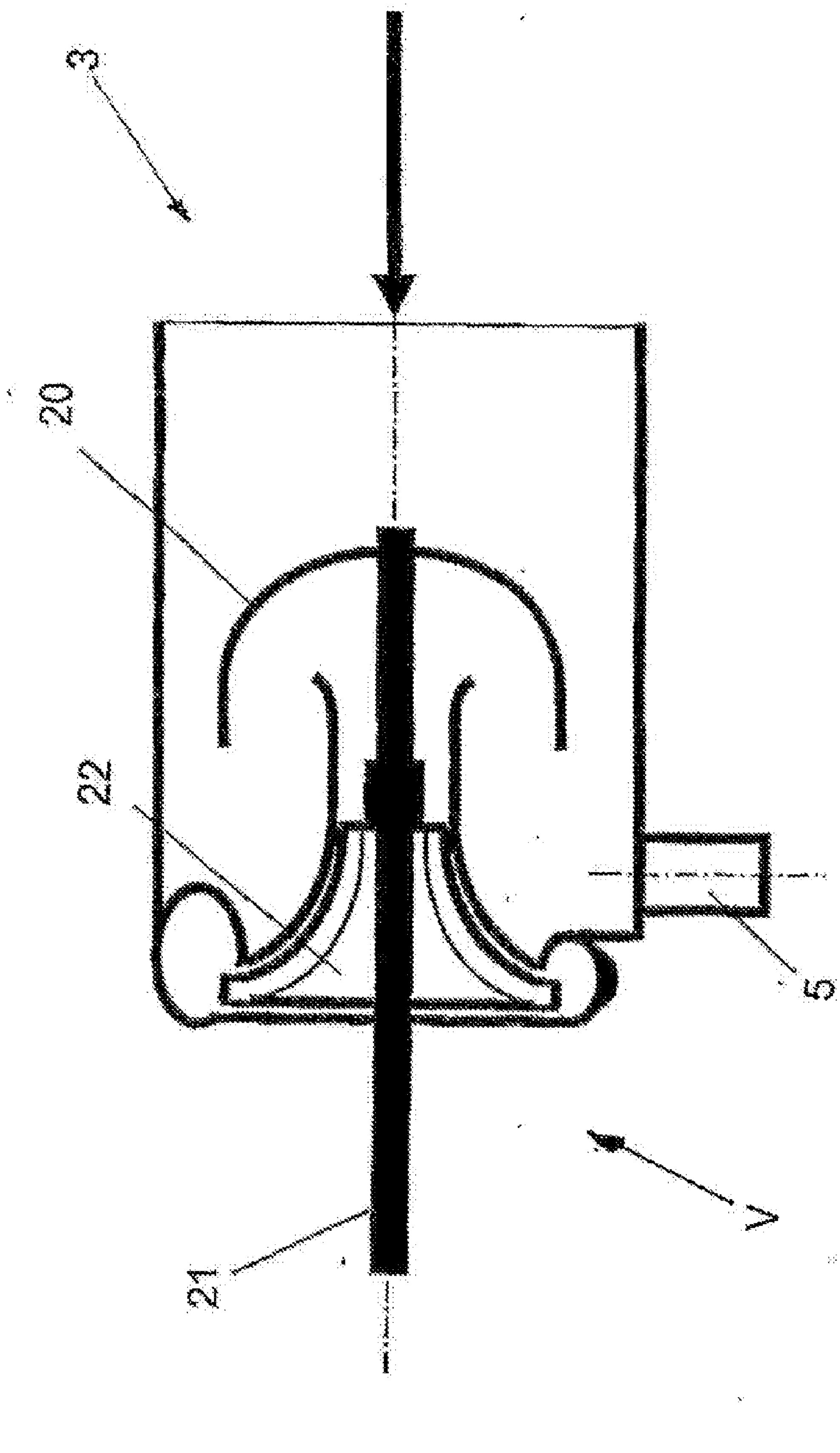


Fig. 9

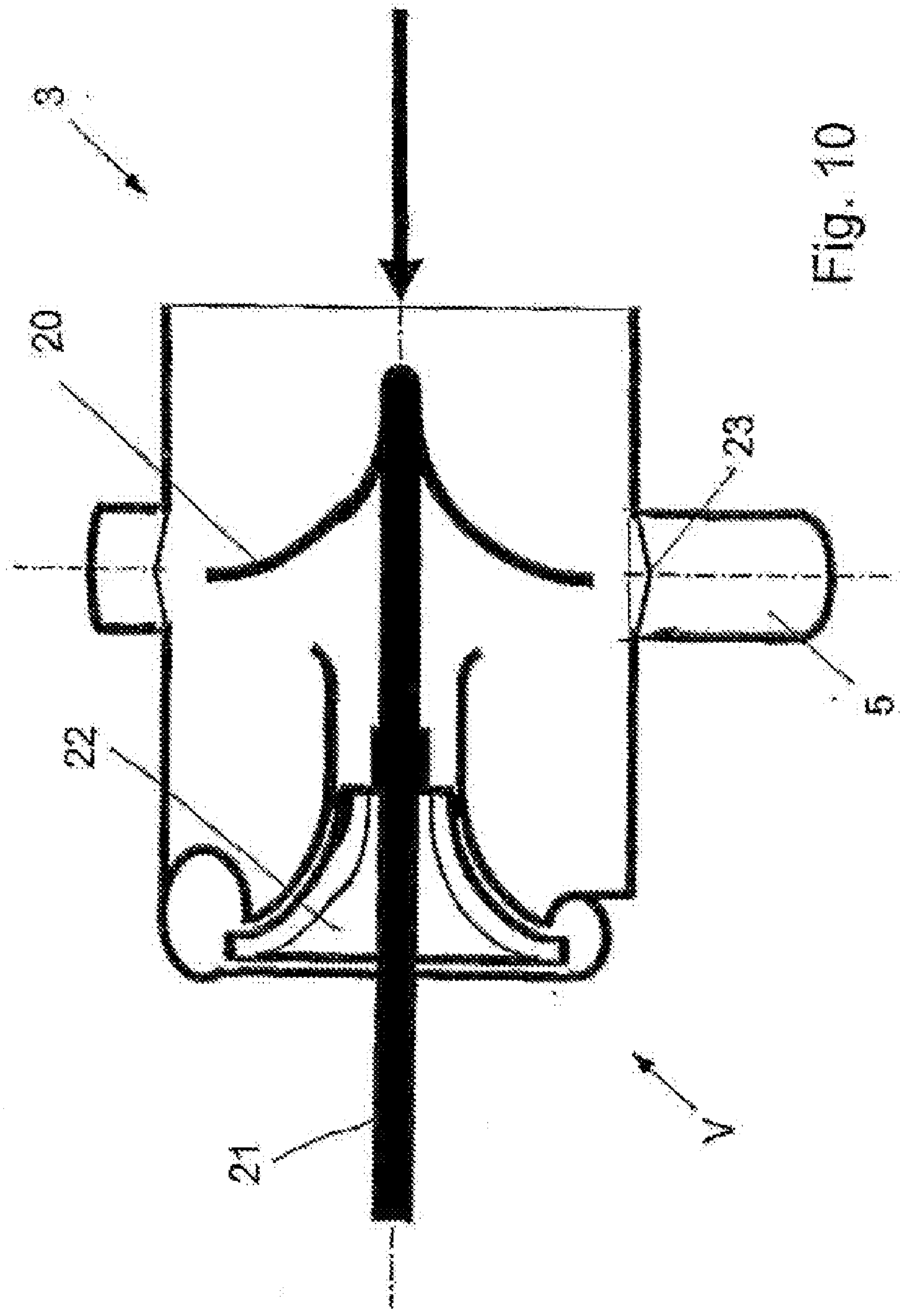


Fig. 10

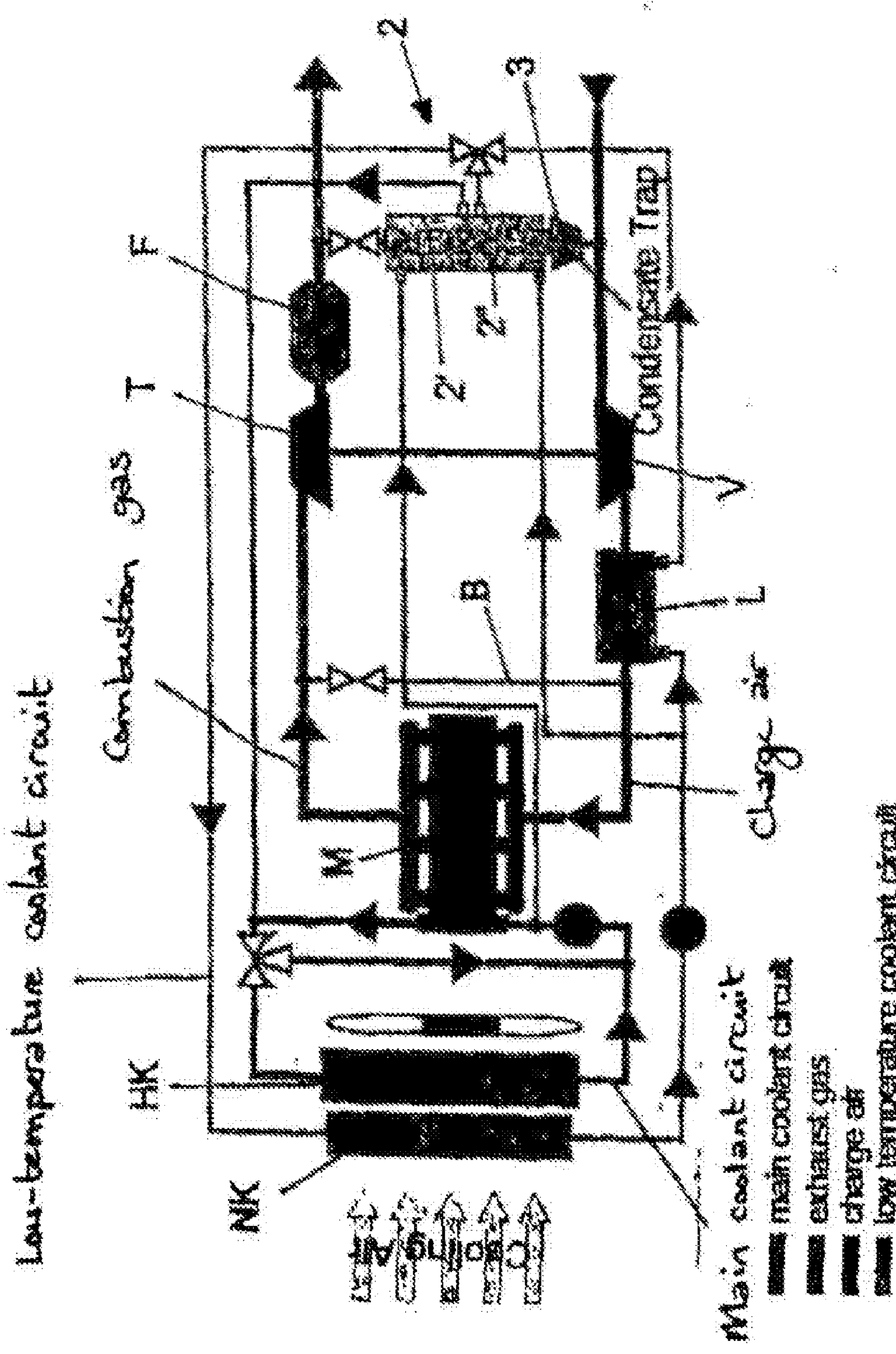

Low-temperature coolant circuit
Combustion gas
charge air
Main coolant circuit
Condensate Trap
Cooling Air
HK
NK
M
B
T
F
V
L
2
3
2'
2''
main coolant circuit
exhaust gas
charge air
low temperature coolant circuit

Fig. 11

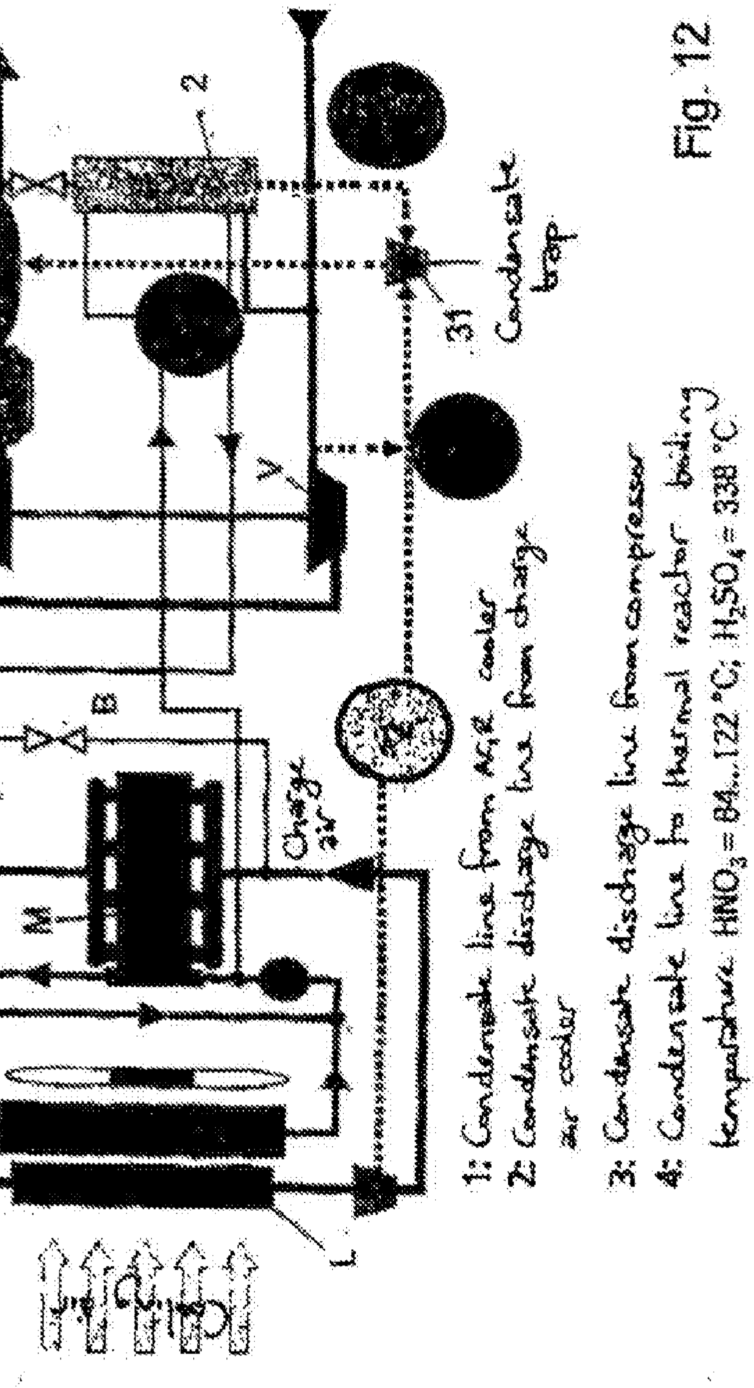

Cooling circuit
Combustion gas
Thermal reactor 32
30
2
F
T
V
B
M
L
Charge air
Condensate trap
31
Cooling air
1: Condensate line from AGR cooler
2: Condensate discharge line from charge air cooler
3: Condensate discharge line from compressor
4: Condensate line to thermal reactor boiling temperature HNO3 = 84...122 °C; H2SO4 = 338 °C

Fig. 12

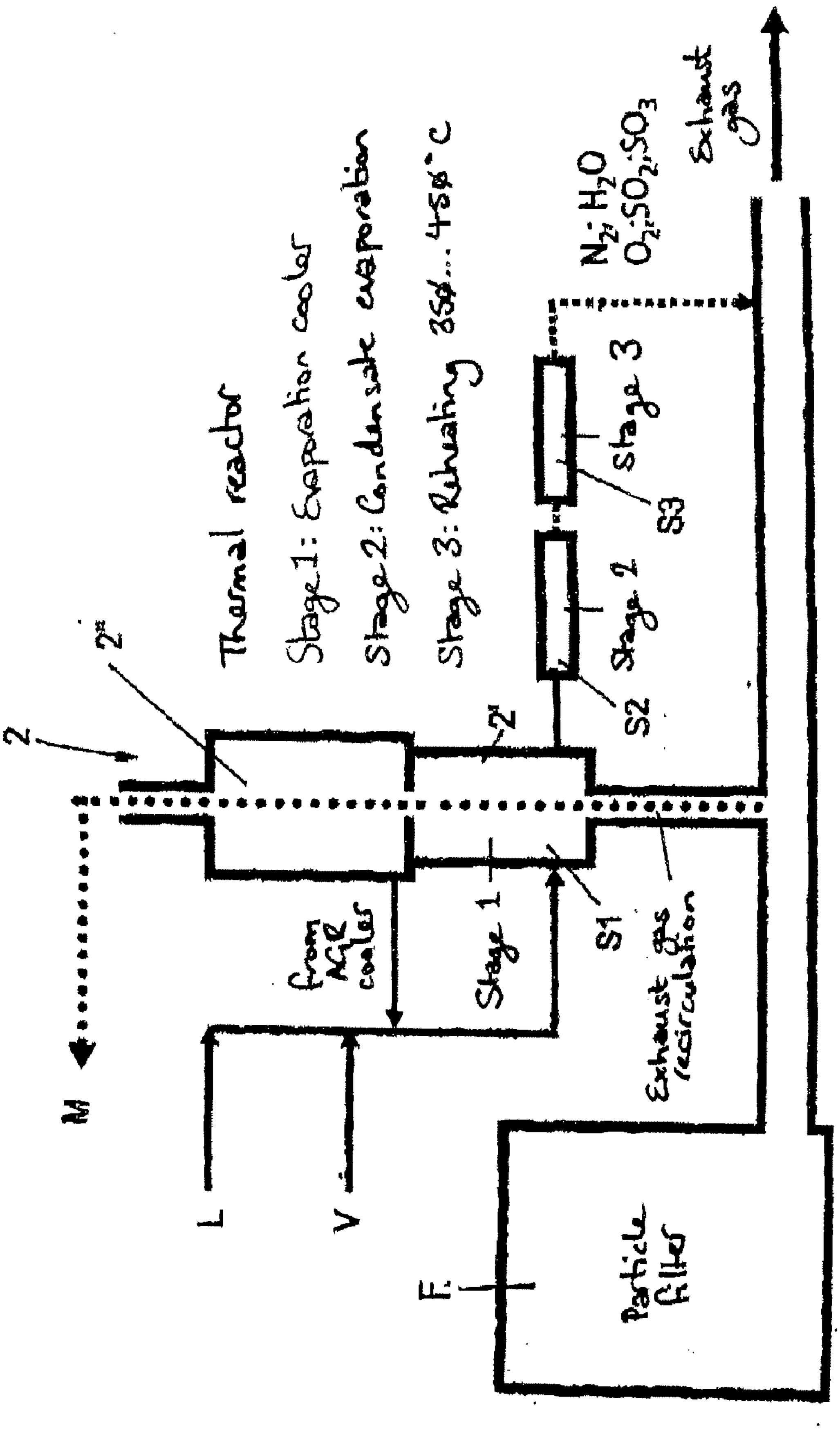

Thermal reactor
Stage 1: Evaporation cooler
Stage 2: Condensate evaporation
Stage 3: Reheating 350...450° C
2
2*
2*
M
L
V
F
from AGR cooler
Stage 1
S1
Stage 2
S2
Stage 3
S3
Exhaust gas recirculation
Particle filter
N_2; H_2O
O_2; SO_2; SO_3
Exhaust gas

Fig. 13

CONDENSER IN A TURBO-COMPRESSOR SYSTEM AND METHOD FOR OPERATING ONE SUCH SYSTEM

[0001] The invention relates to a turbocharger arrangement and a method for operating a turbocharger according to the preamble of claim **1** and claim **19**, respectively.

[0002] In order to reduce the emissions of particles and nitrogen oxides in diesel engines it is known to recirculate exhaust gas, both high-pressure exhaust gas recirculation and low-pressure exhaust gas recirculation being possible. In this context, the exhaust gas stream is cooled to temperatures of approximately 150° C. to 200° C. and mixed into the intake air. At these temperatures of the cooled intake air, a partial stream of the engine coolant is generally used as a cooling medium in the exhaust gas cooler but it is also known to use other coolants. The exhaust gas recirculation becomes more effective as the gas outlet temperatures at the exhaust gas cooler are reduced.

[0003] In the high-pressure exhaust gas recirculation, exhaust gas is usually extracted upstream of the turbine and fed to the charge air downstream of the charge air cooler. The recirculated exhaust gas is cooled by means of the hot engine coolant so that owing to the high temperatures an exhaust gas condensate is usually not produced. The high-pressure exhaust gas recirculation brings about a significant reduction in the nitrogen oxide emission but is associated with a simultaneous rise in the emission of particles. The emission of particles or fine dust can be reduced by means of particle filters.

[0004] During the low-pressure exhaust gas recirculation the exhaust gas is extracted from the exhaust gas stream downstream of the turbine, preferably downstream of a particle filter, cooled and fed to the compressor on the inlet side. Owing to the greater degree of cooling of the recirculated exhaust gas, a further reduction in the emission of nitrogen oxides is possible but owing to the high degree of cooling of the recirculated exhaust gas condensate forms which is highly acidic, essentially due to the nitric acid HNO_3 formed, so that corrosion occurs. If condensate vapor is fed to the compressor, it can additionally damage the compressor because its high rotational speed (approximately 120 000 to 150 **000** rpm).

[0005] In utility vehicles, in addition to the recirculation of exhaust gas in order to reduce the emission of nitrogen oxide, the SCR method (Selective Catalytic Reduction) is also known, in which method ammonia is produced either from ammonium carbamate or aqueous urea solution, and said ammonia catalytically converts the nitrogen oxide generated by the engine into the innocuous components nitrogen and water. However, this method has the disadvantage that an additional operating substance has to be carried in the vehicle.

[0006] Taking this prior art as a starting point, the object of the invention is to make available an improved turbocharger arrangement and a method for operating a turbocharger with which the risk of corrosion is as low as possible. The object is achieved by means of a turbocharger arrangement and a method having the features of claim **1** and of claim **19**. Advantageous refinements are the subject matter of the subclaims.

[0007] In the text which follows, charge air is to be understood as referring to both the intake air and to the intake air mixed with the recirculated exhaust gas.

[0008] According to the invention, a turbocharger arrangement, in particular of a motor vehicle having an internal combustion engine, is provided with exhaust gas recirculation, the arrangement having an exhaust gas cooler and a charge air cooler for cooling recirculated exhaust gas and/or charge air and a compressor for compressing the charge air and a condensate separator. By means of the condensate separator, the corrosive component of the exhaust gas which is located in the condensate which forms when the temperature reaches and drops below the dew point temperature, can be removed from the exhaust gas stream or the charge air stream and it can be ensured that condensate which promotes possibly occurring corrosion of the components does not collect in the following region or only does so to a minimum degree. The condensate separator is preferably arranged here directly downstream of the cooler for cooling the recirculated exhaust gas and/or or downstream of the charge air cooler and/or directly upstream of the charge air compressor.

[0009] The condensate separator can preferably be a centrifugal separator or cyclone separator. Alternatively it is also possible to use another turbulence generator which conveys outward condensate droplets located in an air stream so that said droplets can be carried away. Any other identically acting devices are also possible.

[0010] In addition, it is possible to use a filter, for example composed of stainless steel mesh or plastic mesh or non-woven which serves as a condensate separator.

[0011] In all cases the separation of condensate can take place in multiple stages in order to increase the efficiency. At the same time it is also possible to combine different condensate separators with one another as desired.

[0012] In order to be able to carry the condensate out of a collector vessel or the like, a valve is preferably provided for throttling the exhaust gas stream or the charge air stream so that the pressure level can be raised and the condensate can be carried away without additional resources. Alternatively it is also possible to use resources such as, for example, a pump or some other arrangement which permits a limited pressure increase in the collector vessel.

[0013] A nonreturn valve which permits the condensate to flow out but prevents condensate and/or air from flowing back from the outside can be provided at the condensate outflow.

[0014] In addition, the condensate outflow can have such a discharge gradient that the force due to weight acting on the condensate corresponds at least to the intake pressure so that the condensate can be prevented from being sucked back.

[0015] The condensate separator is preferably arranged directly downstream of the cooler, in particular preferably directly downstream of the exhaust gas cooler. An arrangement downstream of the charge air cooler is also appropriate. In order to protect the compressor against damage by condensate droplets, an arrangement directly upstream of the compressor is also appropriate. In this context is it possible to use the shaft of the compressor advantageously as a drive or as part of a centrifugal separator.

[0016] The condensate separator must additionally be arranged in a region in which condensate droplets are present. This is usually the case in a region in which the temperature of the exhaust gas stream or of the charge air stream reaches or drops below the dew point (taking into account the other parameters such as, in particular, pressure and chemical composition).

[0017] The exhaust gas or the charge air are deflected, in particular have a speed component applied to them in the tangential direction in a region in which the exhaust gas or the charge air has a temperature which corresponds to the dew point or drops below it, with the result that a rotational movement is preferably superimposed on the longitudinal movement but it may also be sufficient to deflect the air stream. As a result of the speed component in the tangential direction, the condensate droplets which form are moved outwards and can be deposited on the wall, where they collect, and can be conveyed onward and carried away. The average tangential speed component in the region of the separation of the condensate is at least as large as the average speed component in the longitudinal direction, preferably at least twice as large.

[0018] The condensate separator is preferably coupled or permanently connected to the shaft of the compressor so that a high rotational speed is possible with a small degree of structural complexity and without an additional drive.

[0019] The condensate separator preferably has an expeller element or centrifuge element which is arranged on the shaft in a rotationally fixed fashion or formed by a region of the shaft. This element which also rotates is preferably fabricated from a lightweight metal or a lightweight alloy such as aluminum, titanium or magnesium, or from a plastic. Alternatively or additionally it can exhibit a surface coating, preferably an oxale layer, which protects it against corrosion. The element is preferably designed in terms of flow dynamics in such a way that despite the deflection no eddies are generated. In addition, it is minimized in terms of its mass in order to avoid mass inertia forces.

[0020] The expeller element or centrifuge element is preferably arranged upstream of the impeller wheel of the compressor in the normal direction of flow of the charge air and preferably deflects the charge air stream by at least 90°, preferably by two times 180°. In particular, a Z-like deflection through two times approximately 180° brings about very good separation of the condensate drops, with some of the condensate drops becoming deposited on the body and being thrown from there against the inner duct wall or housing wall owing to the centrifugal force. In the process, the kinetic energy of the condensate drops can be used to carry the condensate away from the interior.

[0021] The condensate separator is preferably arranged in the compressor housing and/or designed so as to be integrated into the compressor housing. At the same time, the compressor housing preferably has bore holes for the condensate outlet.

[0022] The arrangement preferably has a thermal condensate disposal means which permits the condensate to be detoxified so that the acids contained in the condensate, in particular the nitric acid, the sulfuric acid and the sulfurous acid are converted into their innocuous gases and water. These can subsequently be added to the exhaust gas and discharged into the surroundings via the exhaust.

[0023] The thermal condensate disposal means is preferably of multi-stage design, in particular in three stages. In this context, the heat exchanger which is heated by exhaust gas for heating the condensate is provided as the first stage. A thermal reactor which preferably comprises a PTC heating element and powers down automatically if no condensate occurs is preferably provided as a second stage. A further thermal reactor for residual heating is preferably provided as a third stage, in particular in the form of an electric heating element which heats the evaporated condensate to 350 to 450° C. so that the nitric acid vapor is converted into its innocuous components of nitrogen, water and oxygen. Installations for increasing the surface are preferably provided, in particular in the thermal reactor of the third stage, so that the chemical process sequence can be optimized. A thermal condensate disposal means can be provided for each condensate separator, but a common condensate disposal means is preferably provided for a plurality of condensate separators.

[0024] The heating means of the thermal condensate disposal means can preferably be operated in a clocked fashion at low operating temperatures (122° C.) which bring about the formation of NO_2, in order to permit, for example, load-dependent metering of the NO_2 so that the NO_x limiting values are complied with.

[0025] Likewise, an additional blower can be provided which ensures compliance with the MAK values, irrespective of the functioning of the condensate disposal means.

[0026] Lines which have an automatic delivery effect owing to capillary forces and/or their arrangement are preferably provided between the condensate separator and condensate disposal means so that pumps can be dispersed with.

[0027] Turbocharger arrangements are explained below in detail by means of a plurality of exemplary embodiments and with reference to the drawing, in which:

[0028] FIG. **1** is a schematic basic view of a device for cooling exhaust gas such as can be used in a turbocharger arrangement according to the invention,

[0029] FIG. **2** is a schematic view of a first exemplary embodiment,

[0030] FIG. **3** is a schematic view of a second exemplary embodiment,

[0031] FIG. **4** is a schematic view of a third exemplary embodiment,

[0032] FIG. **5** is a schematic view of a fourth exemplary embodiment,

[0033] FIG. **6** is a schematic view of a fifth exemplary embodiment,

[0034] FIG. **7** is a schematic illustration of a turbocharger arrangement with high-pressure exhaust gas recirculation,

[0035] FIG. **8** is a schematic illustration of a turbocharger arrangement with low-pressure exhaust gas recirculation,

[0036] FIG. **9** is a schematic view of a seventh exemplary embodiment with a first variant of a centrifugal separator,

[0037] FIG. **10** is a schematic view of an eighth exemplary embodiment with a second variant of a centrifugal separator,

[0038] FIG. **11** is a schematic illustration of a turbocharger arrangement with low-pressure exhaust gas recirculation with two-stage cooling of the recirculated exhaust gas,

[0039] FIG. **12** is a schematic illustration of a turbocharger arrangement with low-pressure exhaust gas recirculation with thermal condensate disposal means, and

[0040] FIG. **13** is a schematic detailed illustration of the thermal condensate disposal means in FIG. **12**.

[0041] FIG. **1** shows a small detail of a turbocharger arrangement. Here, a device **1** for cooling recirculated exhaust gas of a motor vehicle with an internal combustion engine is illustrated, said device having a condensate separator **3** which is arranged downstream of an exhaust gas cooler **2** which is cooled by coolant and has an exhaust gas outlet **4** and a condensate outlet **5**. The direction of flow of the exhaust gas stream is indicated by arrows in FIG. **1**. The function, like those in the exemplary embodiments 1 to 5 described below, is the same in each case, specifically the condensate separator **3** extracts the moisture as far as possible from the exhaust gas stream which is cooled by the exhaust gas cooler **2** to approximately 150° C. (temperature below dew point taking into account the other parameter such as, in particular, pressure and chemical composition) directly after the discharge from the exhaust gas cooler **2**. The dry exhaust gas stream passes via an immersion pipe **6** out of the condensate separator **3** and is subsequently mixed with the intake air. The resulting charge air stream is compressed further, cooled in the charge air cooler and subsequently fed to the turbocharger (not illustrated).

[0042] In the present case, the recirculated exhaust gas stream has passed through a particle filter before branching off from the entire exhaust gas stream so that, apart from the separation of the condensate there is as far as possible no separation of particles, in particular no relatively large particles, which become deposited and as a result increase the maintenance expenditure. However, in particular small particles can serve as condensation nuclei and have a positive effect on condensation.

[0043] In this context, according to the further five exemplary embodiments the condensate droplets are separated in the condensate separator **3** by making the exhaust gas stream rotate so that the condensation droplets are not only entrained by the exhaust gas stream in the axial direction but also in particular conveyed outward and collect largely on the wall from where they drop downward as a result of gravity, and can thus be carried away. The pressure loss as a result of the condensate separator **3** is relatively low here. Owing to the separation of the aggressive condensate, the components arranged downstream of it are protected so that the risk of corrosion can be significantly reduced.

[0044] According to the first exemplary embodiment illustrated in FIG. **2**, a centrifugal separator **3** which is in principle conventional is provided as a condensate separator **3** which is part of the device **1**. The condensate which is precipitated flows downward due to gravity through the condensate outlet **5** where an opening with a collector vessel **7** in which the condensate is collected is arranged. The collector vessel **7** is emptied when necessary. It is to be noted in this context that compared to the surroundings a partial vacuum prevails so that the condensate has to be sucked away unless there is an increase in pressure, for example due to the exhaust gas stream becoming blocked. A detailed description of possible centrifugal separators will be provided at a later point with reference to FIGS. **9** and **10**.

[0045] According to the second exemplary embodiment illustrated in FIG. **3**, a shutoff valve **8** which is arranged in the exhaust gas stream is provided in order to bring about an increase in pressure. If the condensate is to be carried away, the shutoff valve **8** is briefly closed so that the pressure in the device rises and the condensate can flow away. It can be stored in a collector vessel (not illustrated) until said vessel is emptied.

[0046] According to the third exemplary embodiment illustrated in FIG. **4**, which corresponds essentially to the first exemplary embodiment, a pump **9** is arranged downstream of the collector vessel **7** and is activated automatically when a specific filling level of the collector vessel **7** is reached so that, in particular in the case of a low-pressure exhaust gas recirculating means which is connected to a lower pressure than the ambient level, the exhaust gas stream does not need to become blocked as is necessary in the second exemplary embodiment in order to raise the partial vacuum in the collector vessel **7** to the ambient level.

[0047] According to the fourth exemplary embodiment illustrated in FIG. **5**, a further possible way of increasing the pressure in the collector vessel **7** is to provide two valves **10** at the condensate inlet and condensate outlet thereof and a thin hose **11** with a control valve **12** which connects the collector vessel **7** to the high-pressure side of the charge air line so that when the control valve **12** is opened the valve **10** on the condensate inlet is automatically closed, the pressure in the collector vessel **7** rises and when a pressure level which is raised compared to the surroundings is reached the second valve **10** at the condensate outlet opens automatically so that the condensate can be carried away.

[0048] Of course, other variants for increasing the pressure in the collector vessel in order to carry away the condensate are also possible.

[0049] According to the fifth exemplary embodiment illustrated in FIG. **6**, a turbulence generator **13** is provided in conjunction with a downstream, annular duct **14** as a condensate separator **3** and is integrated into the line downstream of the exhaust gas cooler **2**. The turbulence generator **13** superimposes a rotational movement on the exhaust gas stream so that again the condensate droplets which are formed downstream of the exhaust gas cooler **2** owing to the reduced temperature are carried outward and deposited on the wall. The speed component of the exhaust gas stream in the longitudinal direction carries along the condensate in the longitudinal direction and thus passes into the duct **14** where it is carried away downward and collects in a collector vessel **7** in accordance with the first exemplary embodiment. For example, measures corresponding to the previously described exemplary embodiments are possible for emptying the collector vessel **7**, in particular in the case of a low-pressure exhaust gas recirculation means.

[0050] The condensate separator does not necessarily need to be arranged directly downstream of the exhaust gas cooler. For example, an arrangement with a subsequent charge air cooler is also appropriate, in particular if the temperature only reaches or drops below the dew point there so that in this case the charge air which is composed of the intake air and the recirculated exhaust gas is cooled. Correspondingly, it is in principle also possible to dry the pure exhaust air.

[0051] According to a sixth exemplary embodiment (not illustrated in the drawing), a filter which has a plastic nonwoven is arranged as a condensate separator downstream of the exhaust gas cooler. The condensate which is formed at said filter collects and runs away downward where it is collected in a collector vessel.

[0052] FIGS. **7** and **8** illustrate examples of a possible arrangement of a condensate separator **3** for high-pressure exhaust gas recirculation (FIG. **7**) and for low-pressure exhaust gas recirculation (FIG. **8**). In the process, the configuration can be implemented in accordance with the previously described exemplary embodiments in all cases. The lines of the low-pressure side are illustrated in FIGS. **7** and **8** by thick, continuous lines and those of the high-pressure side by dashed lines. The directions of flow are respectively indicated by arrows.

[0053] According to the high-pressure exhaust gas recirculation means illustrated in FIG. **7**, the branching off of the exhaust gas to be fed back from the exhaust gas stream which comes from the engine M takes place on the high pressure side, that is to say before the pressure is reduced. The intake air is compressed in a compressor V, flows through a charge air cooler L and subsequently the recirculated and cooled exhaust gas, which is dry after flowing through the condensate separator **3**, is fed to it. The charge air stream is then fed to the engine M.

[0054] FIG. **8** shows an example of a low-pressure exhaust gas recirculation means in which the branching off of the exhaust gas to be fed back from the exhaust gas stream coming from the motor M takes place on the low pressure side, that is to say after a reduction in pressure. In order to prevent the compressor V and the downstream charge air cooler L from being damaged and to protect them against corrosion, said exhaust gas is passed through the exhaust gas cooler **2** and the condensate separator **3**, and only fed to the intake air subsequently. The charge air stream which is then formed by the recirculated exhaust gas and the intake air is cooled in the charge air cooler L and fed to the engine M.

[0055] According to the seventh and eighth exemplary embodiments, a centrifugal separator with a rotating expeller element or centrifuge element **20** can be provided as the condensate separator **3** in order to avoid the dependence on the mass flow stream and to get around the additional overall depth of a cyclone separator which is required for installation, and in the present case the expeller element or centrifuge element **20** is mounted on the shaft **21**, of prolonged design, of the turbocharger on which the compressor impeller wheel **22** is also arranged, said expeller or centrifuge element **20** being mounted upstream of the inlet into the compressor V. In this way, the rotational speed of the centrifugal separator is coupled to the rotational speed of the compressor impeller wheel **22** which is generally 120 000 to 150 000 rpm. The charge air current which carries condensate droplets strikes the expeller element or centrifuge element **20** so that the flow is forcibly deflected and so that a large part of the condensate droplets are deposited on the expeller element or centrifuge element **20**, and as a result of the high rotational speed they are thrown by the latter in the outward direction where they collect and flow in the direction of the condensate outlet **5**. The deflection of the charge air stream on the basis of the expeller element or centrifuge element **20** in conjunction with the compressor inlet is configured geometrically here in such a way that further condensate droplets which have not been deposited on the expeller element or centrifuge element **20** are also separated.

[0056] According to the seventh exemplary embodiment of a condensate separator illustrated in FIG. **9**, the expeller element or centrifuge element **20** is embodied in the manner of a cup, the opening pointing in the direction of the compressor V. Owing to the Z like deflection of the charge air current, by 2× approximately 180° here, most of the condensate droplets are precipitated before the charge air arrives at the compressor V. The expeller element or centrifuge element **20** which is fabricated from an aluminum alloy is plugged onto the end of the shaft **21** and soldered to it.

[0057] FIG. **10** shows an expeller element or centrifuge element **20** for carrying away the condensate in a radial manner according to the eighth exemplary embodiment for a condensate separator **3**. Here, the air is deflected outwards through approximately $9^{\circ\circ}$ so that the condensate droplets strike the expeller element or centrifuge element **20** from where they are thrown outward with high kinetic energy due to the centrifugal force into an annular duct which leads to the condensate outlet **5** and which has a schematically indicated valve mechanism **23** which lets through the condensate droplets which strike it with high kinetic energy but prevents condensate from flowing back into the compressor space. The expeller element or centrifuge element **20** which is fabricated from plastic here is plugged onto the end of the shaft **21** and bonded to it, and, as an additional securing means, the shaft end has a hexagonal shape and the expeller element or centrifuge element **20** has a corresponding internal shape.

[0058] FIG. **11** illustrates the low-pressure exhaust gas recirculation means with two-stage cooling of the recirculated exhaust gas (exhaust gas cooler **2**) in addition to the charge air cooling means (charge air cooler L) which has a single stage (here). The exhaust gas coming from the engine M flows through the turbine T here and flows, in the relaxed, cooled state, through a filter F which is arranged downstream and by means of which particles are removed from the exhaust gas. At a branching junction it is possible for some of the exhaust gas from which particles have been removed to be recirculated under valve control and for the rest of the exhaust gas to pass outwards through the exhaust. The recirculated quantity of exhaust gas is determined here by the pressure gradient which occurs between the exhaust gas counter pressure and the intake partial vacuum so that high exhaust gas recirculation rates are possible with simple means.

[0059] The recirculated part of the exhaust gas is through a two-stage exhaust gas cooler **2**, with precooling being carried out in the first stage **2'** by means of the engine coolant which circulates in an otherwise conventional engine cooling circuit. Where necessary, a further reduction in the exhaust gas temperature occurs in the second stage **2''**. The second stage 2" is part of a low-temperature cooling circuit. The latter has an air-cooled low-temperature cooler NK, downstream of which the high-temperature cooler HK which cools the engine coolant is arranged in the air stream, a compressor K for circulating the coolant and a charge air cooler L and the second stage 2" of the exhaust gas cooler 2 in parallel branches, the coolant distribution being controlled using valves.

[0060] In addition, a bypass B which is made available when necessary under valve control, which runs parallel to the engine M and can conduct charge air past it is provided for the charge air stream or a part thereof.

[0061] As is apparent from FIG. 11, a condensate separator 3, by means of which condensate can be removed from the cold, recirculated exhaust gas before it is mixed with the sucked-in fresh air is provided downstream of the second stage" of the exhaust gas cooler 2. Here, although not illustrated in more detail, a further condensate separator in particular a centrifugal separator such as is described above with reference to FIGS. 9 or 10, is arranged directly upstream of the compressor V.

[0062] In order to dispose of the condensate which collects and which is classified as a hazardous material and therefore cannot be stored onboard a vehicle, a thermal condensate disposal means 30 is provided. In said means, the acids which are formed can be converted into innocuous components using a multi-stage thermal reactor. In addition, the condensate which is formed can be used to precool the recirculated exhaust gas.

[0063] An example of the arrangement of such a condensate disposal means 30 in a low-pressure exhaust gas recirculation means is illustrated schematically in FIGS. 12 and 13. Here, condensate which is collected at the exhaust gas cooler 2, upstream of the compressor V and in or downstream of the charge air cooler L is carried via lines to a central condensate collector 31 from which it is fed via a line to a thermal reactor 32 which is part of the thermal condensate disposal means 30. The thermal reactor 32 is arranged downstream of the filter F and integrated into an exhaust manifold of the engine. The lines carrying the condensate, in particular the line from the condensate collector 31 to the thermal reactor 32, have here a cross section which permits the condensate to be conveyed in the form of capillary forces so that it is possible to dispense with pumps. In addition, there is no provision for significant storage of the condensate which occurs in the engine system here but rather the condensate is largely passed on directly to the thermal reactor 32, heated therein and subsequently discharged.

[0064] As is apparent from FIG. 13, the condensate is used to cool the recirculated exhaust gas in a first stage S1, for which purpose a correspondingly embodied heat exchanger forms the first stage 2' of the exhaust gas cooler 2, that is to say is arranged upstream of the inlet of the actual exhaust gas cooler 2 so that essentially the entire enthalpy change of the condensate can be used for the first stage S1 of the means of cooling the exhaust gas. In the process, the condensate is heated. For good thermal transfer, ribs or corresponding measures which enlarge the surfaces are provided for optimizing the transmission of heat from the exhaust gas to the condensate.

[0065] In a second stage S2, the heated condensate is evaporated, with the further heating being carried out here by means of a self-controlling PTC (Positive Thermal Coefficient) heating element to between approximately 250 and 300° C., and subsequent heating to between 350 and 450° C. takes place in a third stage S3. In this context, sufficient energy to activate the PTC heating element is present irrespective of the operating state of the engine. In addition, the PTC heating element is embodied in such a way that it powers down automatically if no condensate has occurred. The residual heating of the evaporated condensate in the third stage is carried out here using an electrically heated tubular heating element which has a surface temperature of 350 to 450° C. and installations or filling elements with a large surface and possibly catalytic effect.

[0066] Owing to the temperatures of the second and third stages S2 and S3, nitric acid decomposes into NO_2, N_2, H_2O and O_2 and sulfuric acid or sulfurous acid into H_2O and SO_2 and SO_3, respectively, according to the following reactions:

$$4\,HNO_3 \rightarrow 4\,NO_2 + 2\,H_2O + O_2$$

$$4\,HNO_3 \rightarrow 2\,N_2 + 2\,H_2O + 5\,O_2$$

$$H_2SO_4 \rightarrow SO_3 + H_2O$$

$$H_2SO_3 \rightarrow SO_2 + H_2O$$

[0067] After the third stage S3, the condensate which is now innocuous is fed to the exhaust gas stream and disposed of via the exhaust.

[0068] In order to ensure that no inadmissible MAK values occur, an additional blower can be provided which ensures that the limiting values are complied with irrespective of the functioning of the condensate disposal means 30.

1. An arrangement, in particular a turbocharger arrangement of a motor vehicle having an internal combustion engine, with exhaust gas recirculation, wherein the arrangement has an exhaust gas cooler and a charge air cooler for cooling recirculated exhaust gas and/or charge air and, a compressor for compressing the charge air, characterized in that the arrangement has at least one condensate separator.

2. The arrangement as claimed in claim 1, wherein the condensate separator is a centrifugal separator or cyclone separator.

3. The arrangement as claimed in claim 1, wherein the condensate separator has a turbulence generator which causes the exhaust gas stream or the charge air stream to rotate so that at least some of the condensate droplets are deposited on the wall.

4. The arrangement as claimed in claim 3, wherein an annular duct with an outflow opening for the condensate is arranged downstream of the turbulence generator.

5. The arrangement as claimed in claim 1, wherein the condensate separator is a filter.

6. The arrangement as claimed in claim 1, wherein multi-stage condensate separation is provided.

7. The arrangement as claimed in claim 1, wherein a collector vessel is arranged at the condensate outlet.

8. The arrangement as claimed in claim 1, wherein a valve is provided for throttling the exhaust gas stream or the charge air stream.

9. The arrangement as claimed in claim 1, wherein a pump is provided for sucking in the collected condensate.

10. The arrangement as claimed in claim 1, wherein the condensate separator is arranged directly downstream of the cooler, in particular the exhaust gas cooler.

11. The arrangement as claimed in claim 1, wherein the condensate separator is arranged in a region in which the temperature of the exhaust gas stream or of the charge air stream reaches or drops below the dew point.

12. The arrangement as claimed in claim 1, wherein the condensate separator is coupled or permanently connected to the shaft of the compressor.

13. The arrangement as claimed in claim 12, wherein the condensate separator has an expeller element or centrifuge element which is arranged on the shaft in a rotationally fixed fashion or formed by a region of the shaft.

14. The arrangement as claimed in claim 13, wherein the expeller element or centrifuge element is arranged upstream of the impeller wheel of the compressor in the normal direction of flow of the charge air and deflects the charge air stream by at least 90°, preferably by two times 180°.

15. The arrangement as claimed in claim 12, wherein the condensate separator is arranged in the compressor housing and/or is designed so as to be integrated into the compressor housing.

16. The arrangement as claimed in claim 1 wherein the arrangement has a thermal condensate disposal means.

17. The arrangement as claimed in claim 16, wherein the thermal condensate disposal means is of multi-stage design.

18. The arrangement as claimed in claim 16, wherein the thermal condensate disposal means is connected to a plurality of condensate separators via lines.

19. A method for operating a turbocharger, in particular of a motor vehicle, having an internal combustion engine in which exhaust gas is recirculated and fed to the charge air, wherein the exhaust gas or charge air is deflected or directed through a filter in a region in which the exhaust gas or the charge air is at a temperature which corresponds to the dew point or drops below it.

20. The method as claimed in claim 19, wherein the exhaust gas stream which flows essentially in a straight direction or the air stream is deflected in a region directly downstream of a cooler, in particular an exhaust gas cooler, or is directed through the filter.

21. The method as claimed in claim 20, wherein a speed component is applied to the in the tangential direction so that a rotational movement is superimposed on the longitudinal movement.

22. The method as claimed in claim 19, wherein the average tangential speed component is at least as large as the average speed component in the longitudinal direction.

23. The method as claimed in claim 19, wherein the average tangential speed component is at least twice as large as the average speed component in the longitudinal direction.

24. The method as claimed in claim 19, wherein the condensate which collects at an expeller element or centrifuge element is thrown outwards by means of centrifugal force.

25. The method as claimed in claim 19, wherein the condensate is evaporated by means of a thermal condensate disposal means, the acids contained in the condensate are converted and the vapor which is produced and/or the gases are fed again to the exhaust gas stream.

* * * * *