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(54) Method and apparatus for burning hydrocarbons and other liquids and gases

(57) The invention relates to a method and apparatus for burning hydrocarbons or other combustible liquids and gases, as well as to the manufacture and use of such an apparatus. An apparatus (APP) has been provided with at least one inlet for a liquid and/or gaseous fuel (FUE) and air (AIR) and at least one outlet (EXHG) for gases for removing the gases (EXHG) generated in the apparatus (APP), as well as at least one measurement and adjustment unit (C) for adjusting the amount of fuel (FUE) and air (AIR), and that the apparatus (APP) has been provided with at least one pre-combustion zone (Cz11, Cz12, Tz1) for the partial combustion of gases, and that the apparatus comprises at least one post-combustion zone (Tz2, Cz21, Cz22) for the combustion of gases generated in pre-combustion, for the reduction of NOx's produced in pre-combustion, and/or for the oxidation of hydrocarbon and carbon monoxide emissions.

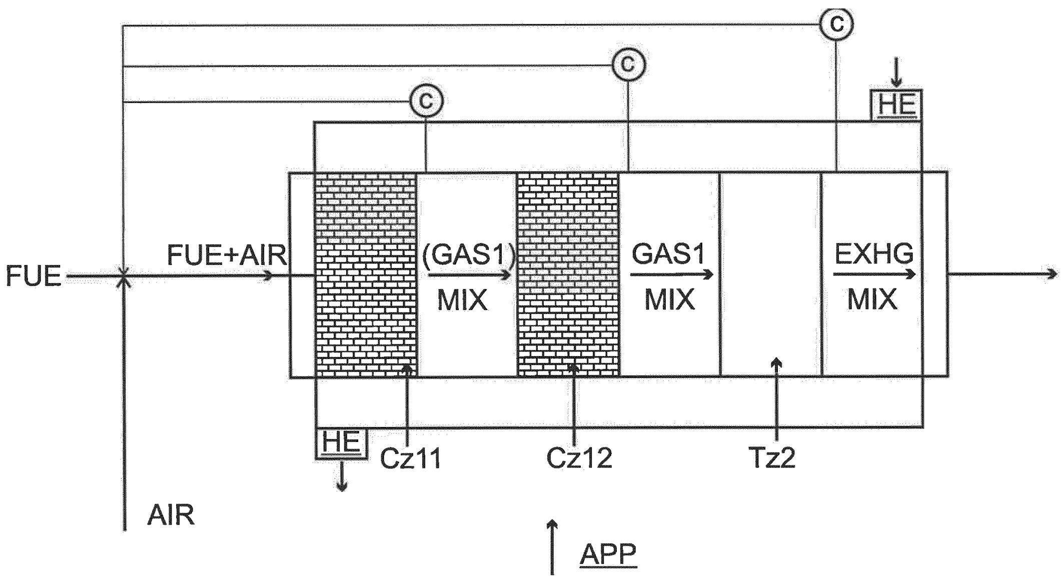

FIG. 1

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Description

[0001] The invention relates to a method and apparatus for burning hydrocarbons or other combustible liquids and gases, as well as to the manufacture and use of such an apparatus.

Background

[0002] Thermal combustion in the production of energy always results in nitrogen oxides (NOx), because at a high temperature (>1000°C) the atmospheric nitrogen or organic nitrogen contained in fuel reacts with combustion air or oxygen contained in fuel. The higher the temperature and the longer the burn time, the more NOx emissions are produced. Another problem is that thermal combustion is never complete, but the flue gas is always left with unburned hydrocarbons (VOC), or carbon monoxide (CO) as a result of incomplete combustion. The resulting amount of these is the higher, the lower is the temperature and the shorter is the burn time, i.e. the emissions produced as a result of reducing (NOx) and oxidizing (HC and CO) reactions require conflicting conditions. Authorities have started to introduce stricter emission regulations based i.a. on BAT (Best Available Technology) resolutions in Europe and BAC (Best Available Control) standards in the USA.

[0003] The main topic in public debate has recently focused on carbon dioxide (CO_2) emissions because of their greenhouse effects. What has been overlooked to some extent is that hydrocarbon emissions are greenhouse gases an order of magnitude more powerful than CO_2. Likewise, nitrogen oxides are greenhouse gases and causes of acid rains and, jointly with VOC gases, are sources of tropospheric ozone, which is highly detrimental to plants and people. For these reasons, the NOx and VOC emission regulations are also being tightened simultaneously with CO_2 emissions. The elimination of nitrogen oxide emissions is expensive as it calls for secondary methods which generally impair efficiency (increase CO_2 emissions) and also increase investment and operating costs. One of the most effective currently employed secondary NOx removal measures is the SCR (Selective Catalytic Reduction) catalytic converter and a selective reducer (ammonia or urea) compatible therewith. The removal of VOC and CO emissions from flue gas is easier. All that is needed for those is an oxidation catalyst. In addition, all above-mentioned compounds require a temperature higher than 250°C and the subsequent recovery of heat. The cleanup of flue gases is expensive in terms of both investment and operating costs. An alternative solution is to oxidize organic fuels so as not to produce the above-mentioned emissions practically at all. This is possible with catalytic combustion and the combination of thermal and catalytic combustion as the gas temperature can be maintained at a sufficiently low level the reaction time very short as compared to thermal combustion. Another possibility is to burn gaseous or liquid fuel thermally with a stoichiometric air-fuel ratio. The NOx produced in thermal combustion can be reduced in a catalytic converter subsequent to the thermal combustion.

[0004] Carbon dioxide is always produced when burning organic compounds. One possibility of exploiting carbon dioxide generated in burning are greenhouses, which need carbon dioxide not only for heating energy but also both for replacing the carbon dioxide consumed in photosynthesis and for fertilizing plants. The double - triple excess of carbon dioxide with respect to what is airborne (about 380 mg/Nm^3) may expedite growth by as much as 40%.

[0005] Greenhouses make up a good target for reducing CO_2 emissions, particularly if the energy is produced with an emission-free biofuel. In this case, the greenhouses would function as carbon sinks. Catalytic combustion, alone or jointly with thermal combustion, is particularly well applicable to the production of energy for greenhouses as plants tolerate neither nitrogen oxides nor ethylene. With regard to these emissions as well, the plants require about a hundred times cleaner air than people.

[0006] The NOx's and VOC's generated in the production of energy needed for industry, traffic and residential heating are a major problem. Together with sunlight, they produce tropospheric ozones harmful for plants and people. Since February 1, 2012, NOx emissions are limited by Californian BAC standards to the level of about 15 mg/Nm^3 (1,4-3 MW facilities). Larger facilities are required to have lower values of 5 mg/Nm^3 for NOx and 20 mg/Nm^3 for VOC and CO emissions. However, the standards vary from state to state. These values are not reachable by thermal combustion alone. Yet, all these limit values can be achieved with catalytic combustion or with a new combination of catalytic and thermal combustion without a subsequent treatment of flue gas.

Description of the invention

[0007] What has been invented now is a method and apparatus for burning hydrocarbons or other combustible gases and liquids, whereby the combustion can be performed in a particularly effective manner. The invention relates also to a method for the manufacture and use of such an apparatus.

[0008] The method and apparatus of the invention are presented in independent claims. In addition, a few preferred embodiments of the invention are presented in dependent claims.

[0009] An apparatus APP of the invention has been provided with or arranged to comprise at least one inlet for a liquid and/or gaseous fuel and air and at least one outlet for gases for removing the gases generated in the apparatus, as well as at least one measurement and adjustment unit for adjusting the amount of fuel and air, and that the apparatus APP has been provided with at least one pre-combustion zone for the partial combustion of gases, and that the apparatus comprises at least one post-combustion zone for the combustion of gases generated in pre-combustion, for the reduction of NOx's produced in pre-combustion, and/or for the oxidation of hydrocarbon and carbon monoxide emissions.

[0010] According to one object of the invention, at least one of the pre-combustion zones and/or the post-combustion zones is a catalytic zone.

[0011] According to one object of the invention, the apparatus APP is provided with at least one catalytic zone. According to one object of the invention, the apparatus APP is provided with at least one thermal zone. According to one object of the invention, the apparatus APP is provided with at least one catalytic pre-combustion zone and at least one thermal post-combustion zone. According to one object of the invention, the apparatus APP is provided with at least one catalytic pre-combustion zone and at least one catalytic post-combustion zone, According to one object of the invention, the apparatus APP is provided with at least one thermal pre-combustion zone and at least one catalytic post-combustion zone. These are beneficial in certain embodiments of the invention and contribute to improve combustion performance. According to one object of the invention, the apparatus APP is provided with at least one heat exchanger HE for the transfer of heat generated in pre-combustion and/or post-combustion. This gives both economic and technical advantage.

[0012] The method according to the invention comprises respectively at least the following operations:

- the partial pre-combustion of fuel in at least one pre-combustion zone, such that the supplied fuel is burned only partially,
- the post-combustion of pre-combustion-generated gases in at least one post-combustion zone for burning the pre-combustion-generated gases, for the reduction of pre-combustion-generated NOx's, and/or for the oxidation of hydrocarbon and carbon monoxide emissions.

[0013] The apparatus and method can be implemented in one or more configurations. Hence, the apparatus can have its components located in a single assembly or separated from each other by one or more other intervening components or devices. Respectively, operations can also be carried out in a single sequence or can be at least partially distinguished from each other by one or more other intervening operations. These can also be integrated for larger entities.

[0014] The apparatus and method can be used in the combustion of e.g. natural gas, biogas, bioethanol, propane, methanol, ethanol, turpentine, butane, pentane, carbon monoxide, hydrogen, light fuel oil, oil-water emulsion and/or any mixtures thereof.

[0015] According to one object of the invention, the measurement and adjustment unit C is provided with or arranged to comprise at least one Lambda sensor for measuring the oxidation/reduction potential of a flue gas. The inlet of fuel FUE and air AIR into the apparatus APP can be adapted to occur within the Lambda range of 0,5-1,5.

[0016] According to one object of the invention, the combustion temperature is within the range of 400-800 °C. Thus, there will preferably be no substantial NOx emissions.

[0017] If gases have high content of CO, catalytic zone can be selected so that temperature is low, even 200 °C or lower. This significant adds lifetime of catalyst. Then proper temperature can be e.g. 100 °C or more lower than normally. It is thus also in some cases advantageous to have high content of CO in pre-treatment gas and burn it thereafter in catalytic zone.

[0018] According to one object of the invention, the monitoring of NOx emissions is carried out by using a NOx sensor, which is preferably useful for controlling the air-fuel ratio as well.

[0019] According to one object of the invention, the monitoring of CO emissions is carried out by using a CO-sensor, which is preferably useful for controlling the air-fuel ratio as well.

[0020] The apparatus according to one object of the invention comprises either one thermal burner with a liquid or gaseous fuel inlet and at least one catalytic converter for the catalytic combustion of gases and for the reduction of NOx's generated in thermal combustion and for the oxidation of hydrocarbon and carbon monoxide emissions. Since reduction in the process of burning combustible gases necessitates a stoichiometric air-fuel ratio, the apparatus is therefore further provided with at least one Lambda sensor carrying out a measurement for the oxidation/reduction potential of a flue gas, and provided with an air/fuel ratio adjustment system. The monitoring of NOx emissions can be carried out by using a NOx sensor, which can also be used for controlling the air-fuel ratio.

[0021] According to one object of the invention, at least one of the pre-combustion zones and/or the post-combustion zones is a catalytic zone, which has activated portions and non-activated portions for only the partial combustion of fuel and for adjusting the temperature of combustion.

[0022] Thermal combustion in a pre-combustion process can be replaced by one or more catalytic converters, of which the first, and possibly also the second catalytic converter is only partially catalytically coated. According to one object of the invention the catalytic converter honeycomb is provided with activated and non-activated channels side by side.

In this case, the reactions take place in the activated channel with a "cold" unreacted gas proceeding in the adjacent channel. This enables cooling of the high temperature created in the activated channel, since reactions in a catalytic converter occur much more rapidly than thermal combustion. Hence the production of heat can be distributed over several stages. Such a partially coated catalytic converter can be preferably constructed from a metal foil by coating just one side of the foil or by placing an uncoated foil to serve as every other foil. Partial combustion can also be carried out by leaving a larger opening in the middle of the honeycomb or a gap on the outer periphery. The alternatives are plausible in various combinations.

[0023] Catalytic combustion can be carried out with very lean mixtures, which is why the boiler of the invention is able to burn simultaneously several fuels, comprising VOC emissions. The supply of air and fuel for the burner can be controlled with temperatures subsequent to catalytic converters.

[0024] One aspect with burners of the above type is that such burners can be constructed as part of a boiler, which is preferably a tubular heat exchanger so as to enable catalytic converters to be disposed at fixed intervals inside the pipes with water or other liquid flowing outside the pipes. The idea here is that the production of heat is distributed over several stages. Hence, the gas has time to cool prior to the next catalytic converter with heat transferring to liquid. Thereby, the catalytic converter can be kept from overheating and the gas can be kept hot over a longer distance. The catalytic converter's channels are sufficiently small to eliminate the possibility of thermal combustion. The combustion occurs in the form of intense oxidation taking place on catalyst surfaces without a flame. Upon emerging from the catalytic converter, the gas ignites immediately to burn thermally.

[0025] According to one object of the invention, the apparatus comprises at least one thermal pre-treatment zone in fire-tube(s) in the fire-tube boiler and at least one catalytic combustion zone as a post-treatment installed in smoke-tube(s) in the fire-tube boiler. Fire-tube boiler can be e.g. one-way, two-way, three-way or four-way boiler. These embodiments gives essential advantage because it gives very efficient way to control both pre-combustion and post-combustion burning. It is also now possible to optimize place of post-combustion catalytic zone in very advantageously. Catalytic zone can be fixed case by case so that conditions for catalytic burning are optimal even in varying temperatures and boiler loads. Place can be fixed by measuring or e.g. by CFD (computational fluid dynamics). Term "fire-tube boiler" is to be understood in this application also e.g. as shell boiler and water tube boiler. Term "fire-tube" is to be understood in this application also e.g. as furnace, combustion chamber, flame tube, first-pass, fire-box. Term "smoke-tube" is to be understood in this application also e.g. as second pass, convection part, tube(s).

[0026] Temperature in fire-tube is usually over 1000 °C and in smoke-tubes 1000 to 300 °C. Catalytic zone (e.g. three-way catalytic) is usually fixed e.g. to two-way tubes, where conditions for catalytic burning are optimal even in varying temperatures and boiler loads. Place can be fixed by measuring or e.g. by CFD (computational fluid dynamics). In an example in two-way boiler, where temperature in fire-tube is between 1000 to 1750 °C and temperature in smoke tubes was 1000 to 300 °C, three-way catalytic was placed so that current temperature in catalytic zone was about 360 to 860 °C.

[0027] This burner and boiler combination can be constructed from a conventional pipe heat exchanger. Heat transfer can be enhanced by inducing a swirl in the gas. This heat transfer solution is useful for achieving a more effective heat transfer performance despite the lower peak temperature. Enclosed is one example. Likewise, the boiler and burner become smaller in size and lower in costs. There is no need for special materials, and standard solutions such as heat exchangers can be applied.

[0028] Example: In a three-way catalytic converter take place simultaneously the following main reactions:

$$HC+O2\rightarrow H2O+CO2$$

$$CO + 02 \rightarrow CO2$$

$$HC + NOx \rightarrow H2O + CO_2 + N2$$

$$CO + NOx \rightarrow CO2 + N2$$

[0029] Temperature in the catalytic converter may rise to an extraordinary high level (in excess of 1500°C). Therefore, the catalytic converter must be constructed by using highly heat resistant steel grades such as 1.4767, 1.4828, Nicrofer 6025 HT etc. or ceramic honeycomb cells. It is preferred that the catalytic converter be coated with some platinum group metal and a porous coating. Ecocat Oy, among others, has developed a catalytic converter capable of withstanding extraordinarily high temperatures, which is applicable to this purpose. A preferred solution from the standpoint of a favorable combustion result is a mixing metal-core catalytic converter.

[0030] With traditional thermal combustion, it is difficult to reach a NOx level of 50 mg/Nm^3. An attempt to minimize the NOx emission brings forth a hazard of increased hydrocarbon and carbon monoxide emissions due to incomplete burning. An advantage in the present invention is that the combustion process as a whole is very short, nor is a large pre-chamber necessary for burning. The generation of nitrogen oxides increases exponentially as temperature is rising and directly proportionally as a function of burn time. The increase of oxygen amount decreases the formation of NOx's in proportion to the square root of the content.

[0031] The burner has a low maintenance demand and catalytic converters of precious metals have a long service life. The burner consists of a few components easy to disassemble for maintenance.

[0032] Greenhouses would make an excellent target for this technology. In the process of burning propane, the resulting amount of carbon dioxide is 3-times, and in the process of burning natural gas, it is 2-times with respect to the consumption of fuel. It is almost an optimal amount from the standpoint of fertilizing demand for CO_2. At present, the fertilization is primarily carried out with liquefied carbon dioxide, which is mainly produced by a fermentation process, and then purified and liquefied by cooling. This is in total contradiction with current environmental regulations. Another problem is the warming-up and evaporation of CO_2 during storage.

[0033] The catalytic Ultra LowNox, NoVoc and NoCo burner is small in size and attractive in costs. It enables even the strictest emission standards to be attained without post-flue gas treatment. The elimination of final emission percentage is always the most expensive phase.

[0034] The useful fuels comprise nearly all gaseous and several liquid fuels, such as natural gas, biogas, bioethanol, propane, light fuel oil, oil/water emulsions, etc. The most practical are low sulfur fuels and gases not containing halogens. Even the latter can be used, but necessarily with a different catalytic converter and boiler materials. The combustion of sulfur compounds results in the formation of sulfuric acid and the combustion of chlorinated hydrocarbons results in hydrochloric acid.

[0035] The removal of nitrogen oxides unavoidably generated in thermal combustion is difficult and expensive downstream of the boiler. What is most commonly needed is an SCR or SNCR (Selective Catalytic Reduction or Selective Non Catalytic Reduction) catalytic converter and a selective reducer ammonia or urea therefor. In addition to a high acquisition price, there will be a perpetual acquisition expense for the reducer (ammonia or urea), nor is the low NOx level of a catalytic NoNox burner always reachable. The reduction of NOx's generated in thermal combustion and the oxidation of VOC and CO emissions require a temperature higher than 250°C.

[0036] The combined thermal and catalytic burner fulfills the present and tightening future NOx, VOC and CO emission standards without any exhaust gas after-treatment. The catalytic burner is a solution less expensive than any of the reference technologies for the elimination of NOx, HC and CO emissions in energy production.

[0037] The catalytic burner is capable of achieving such low level NOx and ethylene emissions that enable the delivery of flue gases directly into a greenhouse for a CO_2 fertilizer and the use of combustion-generated energy for greenhouse heating. The NOx and ethylene emission standard for greenhouses is about 100 times stricter than the workplace air quality standard for people.

[0038] The catalytic burner is a solution less expensive than any of the reference technologies for the elimination of NOx, HC and CO emissions in energy production.

[0039] It is preferred that the catalytic burner be provided with a mixing honeycomb or some other structure, which enhances material transfer and intensifies oxidation (diffusion of combustion gas molecules in the micropores of a catalytic converter) and at the same time reduces the amount of emissions.

[0040] A few embodiments of the invention are further depicted in figs. 1-3:

- fig. 1 shows an apparatus, comprising two catalytic pre-treatment zones and thermal combustion as a post-treatment
- fig. 2 shows an apparatus, comprising two catalytic pre-treatment zones and catalytic combustion as a post-treatment
- Fig. 3 shows an apparatus, comprising one thermal pre-treatment zone and two catalytic combustions as a post-treatment
- Fig. 4 shows an apparatus comprising one thermal pre-treatment zone in fire-tube and catalytic combustions as a post-treatment installed in smoke-tubes in two-way fire-tube boiler
- Fig. 5 shows an apparatus comprising one thermal pre-treatment zone in fire-flue and catalytic combustions as a post-treatment installed in smoke-tubes in a three-way fire-tube boiler

[0041] . The apparatuses APP of figs. 1-3 are provided with one inlet for a liquid or gaseous fuel FUE and for air AIR and one outlet for gases for removing gases EXHG generated in the apparatus APP, as well as with at least one measurement and adjustment unit C for adjusting the amount of fuel FUE and air AIR. Further depicted in figs. 1-3 are optional extra mixers MIX. The apparatuses comprise the following operations:

- the partial pre-combustion of fuel FUE in at least one pre-combustion zone Cz11, Cz12, Tz1, such that the supplied fuel is burned only partially,
- the post-combustion of pre-combustion-generated gases GAS1 in at least one post-combustion zone Tz2, Cz21, Cz22 for burning the pre-combustion-generated gases, for the reduction of pre-combustion-generated NOx's, and/or for the oxidation of hydrocarbon and carbon monoxide emissions, the pre-combustion and/or post-combustion being carried out in at least one catalytic zone Cz11, Cz12, Cz21, Cz22, which comprises activated channels and non-

activated zones for just partial combustion of the fuel and for adjusting the combustion temperature. The apparatuses APP of figs. 1-3 are provided with a heat exchanger HE for the transfer of heat generated in pre-combustion and/or in post-combustion.

[0042] In figs. 1 and 3, the pre-combustion or post-combustion is carried out in one thermal zone Tz1, Tz2. In fig. 1, the pre-combustion is carried out in two catalytic pre-combustion zones Cz11, Cz12 and the post-combustion is carried out in one thermal post-combustion zone Tz2. In fig. 2, the pre-combustion is carried out in two catalytic pre-combustion zones Cz11, Cz12 and the post-combustion is carried out in one catalytic post-combustion zone Cz21. In fig. 3, the pre-combustion is carried out in one thermal pre-combustion zone Tz1 and the post-combustion is carried out in two catalytic post-combustion zones Cz21, Cz22.

[0043] In figs. 4 and 5 pre-combustion or post-combustion is carried out in one thermal zone Tz1 in fire-tube FLU, such that the supplied fuel is burned only partially. Post-combustion is carried out in catalytic zone(s) Cz21, Cz22 in smoke-tubes FTU for burning the pre-combustion-generated gases, for the reduction of pre-combustion-generated NOx's, and/or for the oxidation of hydrocarbon and carbon monoxide emissions. The apparatuses APP of figs. 4 and 5 are provided with one inlet for a liquid or gaseous fuel FUE and for air AIR and one outlet for gases for removing gases EXHG generated in the apparatus APP, as well as with at least one measurement and adjustment unit C for adjusting the amount of fuel FUE and air AIR. The apparatuses APP of figs. 4 and 5 are provided with a heat exchanger HE for the transfer of heat generated in pre-combustion and in post-combustion.

Claims

1. A method for burning hydrocarbons or other combustible liquids and gases in an apparatus (APP), which is provided with at least one inlet for a liquid or gaseous fuel (FUE) and for air (AIR) and at least one outlet for gases for removing gases (EXHG) generated in the apparatus (APP), as well as with at least one measurement and adjustment unit (C) for adjusting the amount of fuel (FUE) and air (AIR), **characterized in that** the method comprises at least the following operations:

   - the partial pre-combustion of fuel (FUE) in at least one pre-combustion zone (Cz11, Cz12, Tz1), such that the supplied fuel is burned only partially,
   - the post-combustion of pre-combustion-generated gases (GAS1) in at least one post-combustion zone (Cz21, Cz22, Tz2) for burning the pre-combustion-generated gases, for the reduction of pre-combustion-generated NOx's, and/or for the oxidation of hydrocarbon and carbon monoxide emissions.

2. An apparatus (APP) for burning hydrocarbons or other combustible liquids and gases, **characterized in that** the apparatus (APP) has been provided with at least one inlet for a liquid and/or gaseous fuel (FUE) and air (AIR) and at least one outlet (EXHG) for gases for removing the gases (EXHG) generated in the apparatus (APP), as well as at least one measurement and adjustment unit (C) for adjusting the amount of fuel (FUE) and air (AIR), and that the apparatus (APP) has been provided with at least one pre-combustion zone (Cz11, Cz12, Tz1) for the partial combustion of gases, and that the apparatus comprises at least one post-combustion zone (Cz21, Cz22, Tz2) for the combustion of gases generated in pre-combustion, for the reduction of NOx's produced in pre-combustion, and/or for the oxidation of hydrocarbon and carbon monoxide emissions.

3. A method for manufacturing an apparatus (APP) suitable for burning hydrocarbons or other combustible liquids and gases, **characterized in that** the apparatus (APP) provided with at least one inlet for a liquid and/or gaseous fuel (FUE) and air (AIR) and at least one outlet (EXHG) for gases for removing the gases (EXHG) generated in the apparatus (APP), as well as at least one measurement and adjustment unit (C) for adjusting the amount of fuel (FUE) and air (AIR), and that the apparatus (APP) is provided with at least one pre-combustion zone (Cz11, Cz12, Tz1) for the partial combustion of gases, and that the apparatus is provided with at least one post-combustion zone (Cz21, Cz22, Tz2) for the combustion of gases generated in pre-combustion, for the reduction of NOx's produced in pre-combustion, and/or for the oxidation of hydrocarbon and carbon monoxide emissions.

4. The use of the method and/or the apparatus according to claim 1 or 2, for burning hydrocarbons or other combustible liquids and gases, in the combustion of natural gas, biogas, bioethanol, propane, methanol, ethanol, turpentine, butane, pentane, carbon monoxide, hydrogen, light fuel oil, oil/water emulsion and/or any mixtures thereof.

5. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-4, **characterized in that** the pre-combustion and/or

the post-combustion are/is carried out in at least one catalytic zone (Cz11, Cz12, Cz21, Cz22).

6. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-5, **characterized in that** the pre-combustion and/or the post-combustion are/is carried out in at least one thermal zone (Tz1, Tz2).

7. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-6, **characterized in that** the pre-combustion is carried out in at least one thermal pre-combustion zone (Tz1) and the post-combustion is carried out in at least one catalytic post-combustion zone (Cz21, Cz22).

8. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-7, **characterized in that** the pre-combustion is carried out in at least one catalytic pre-combustion zone (Cz11, Cz12) and the post-combustion is carried out in at least one catalytic post-combustion zone (Cz21, Cz22).

9. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-8, **characterized in that** the supply of fuel (FUE) and the supply of air (AIR) into the apparatus (APP) is arranged to occur within the Lambda range of 0,5-1,5.

10. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to claim 9, **characterized in that** Lambda is >1,0 (lean mixture).

11. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to claim 9, **characterized in that** Lambda is <1,0 (rich mixture).

12. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to claim 9, **characterized in** Lambda is 0,99 to 1,01 (stoichiometric air-fuel ratio or near it).

13. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-12, **characterized in that** said apparatus (APP) comprise at least one of catalyst zone (Cz11, Cz12, Cz21, Cz22) having three-way catalytic.

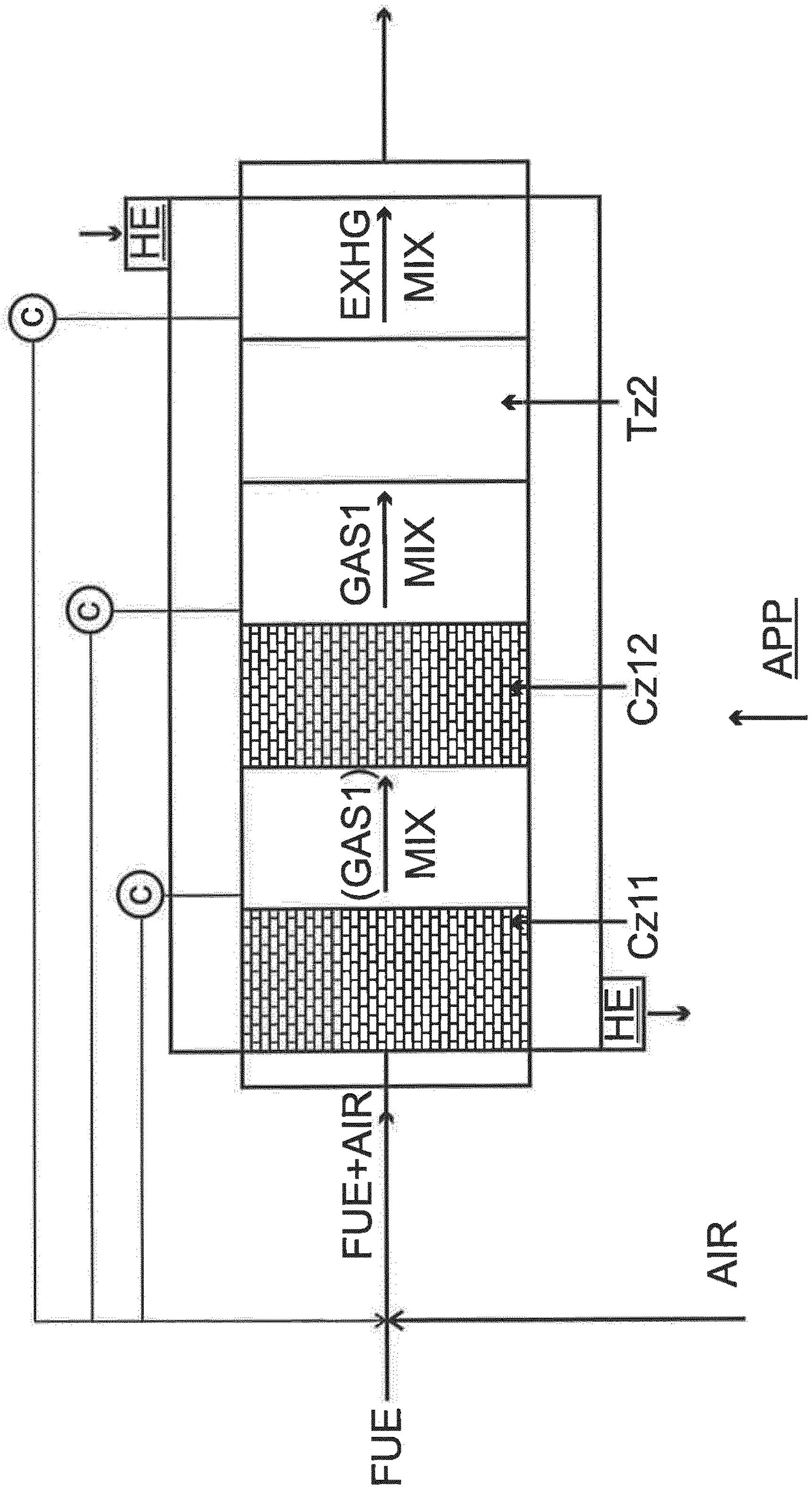
14. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-13, **characterized in that** pre-combustion is arranged in lowered temperature.

15. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-14, **characterized in that** the supply of fuel (FUE) and the supply of air (AIR) into the apparatus (APP) is arranged by monitoring NOx emissions by using a NOx sensor.

16. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-15, **characterized in that** the apparatus (APP) has been provided with at least one heat exchanger (HE) for the transfer of heat generated in pre-combustion and/or in post-combustion.

17. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claims 1-16, **characterized in that** the apparatus (APP) is fire-tube boiler comprising at least one thermal pre-treatment zone (Tz1) in fire-tube(s) FFL and at least one catalytic combustion zone (Cz21, Cz22) as a post-treatment installed in smoke-tube(s) FTU.

18. The method, the apparatus, the method for manufacturing an apparatus (APP) for burning hydrocarbons or other combustible liquids and/or the use according to any of claim 17, **characterized in that** place of post-treatment catalyst(s) (Cz21, Cz22) is arranged according to the burning temperature in smoke-tube(s) FTU and optimized operating temperature of said catalyst(s) (Cz21, Cz22).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Cz12
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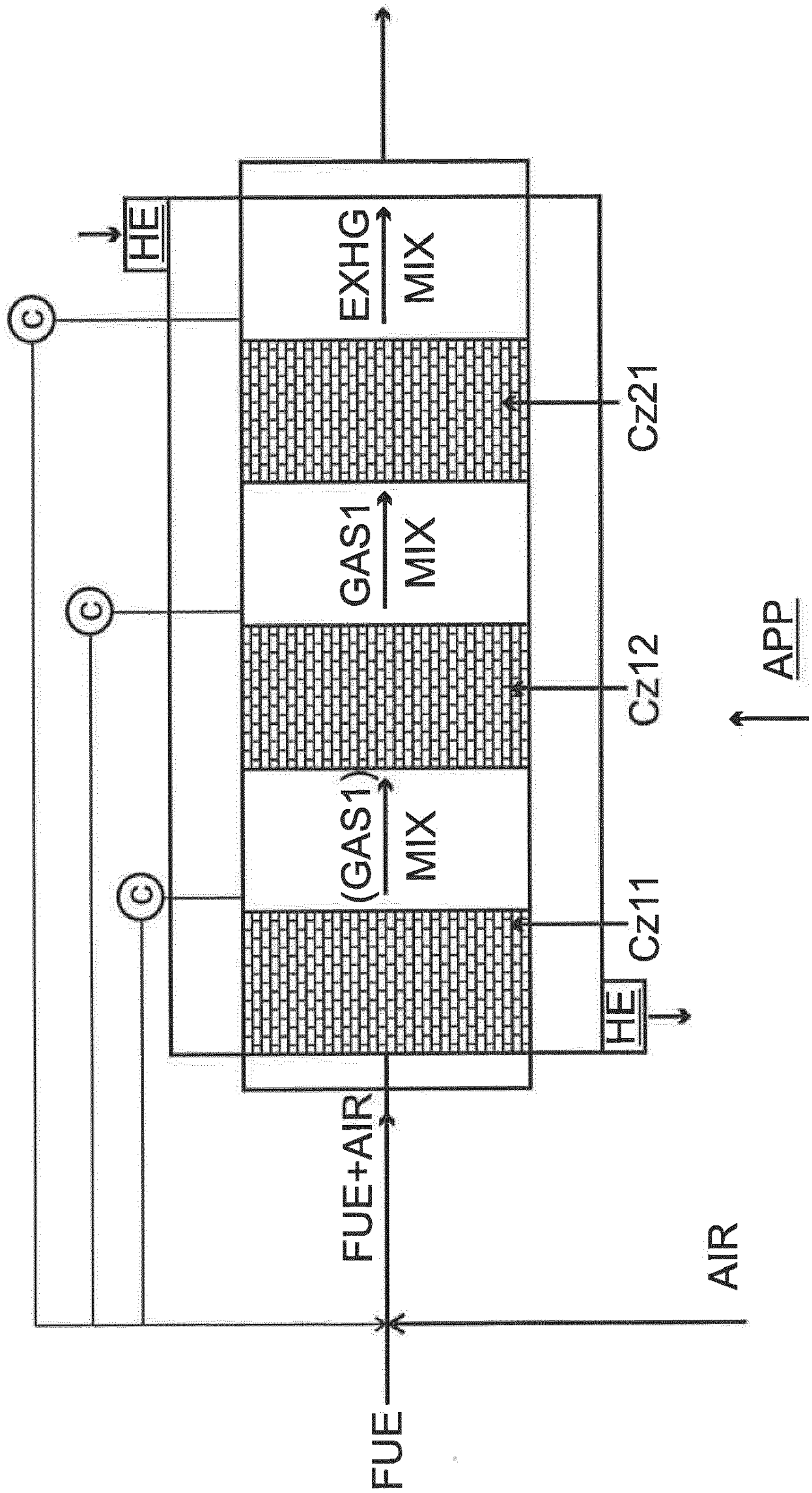
APP
FUE+AIR
FUE
AIR

FIG. 1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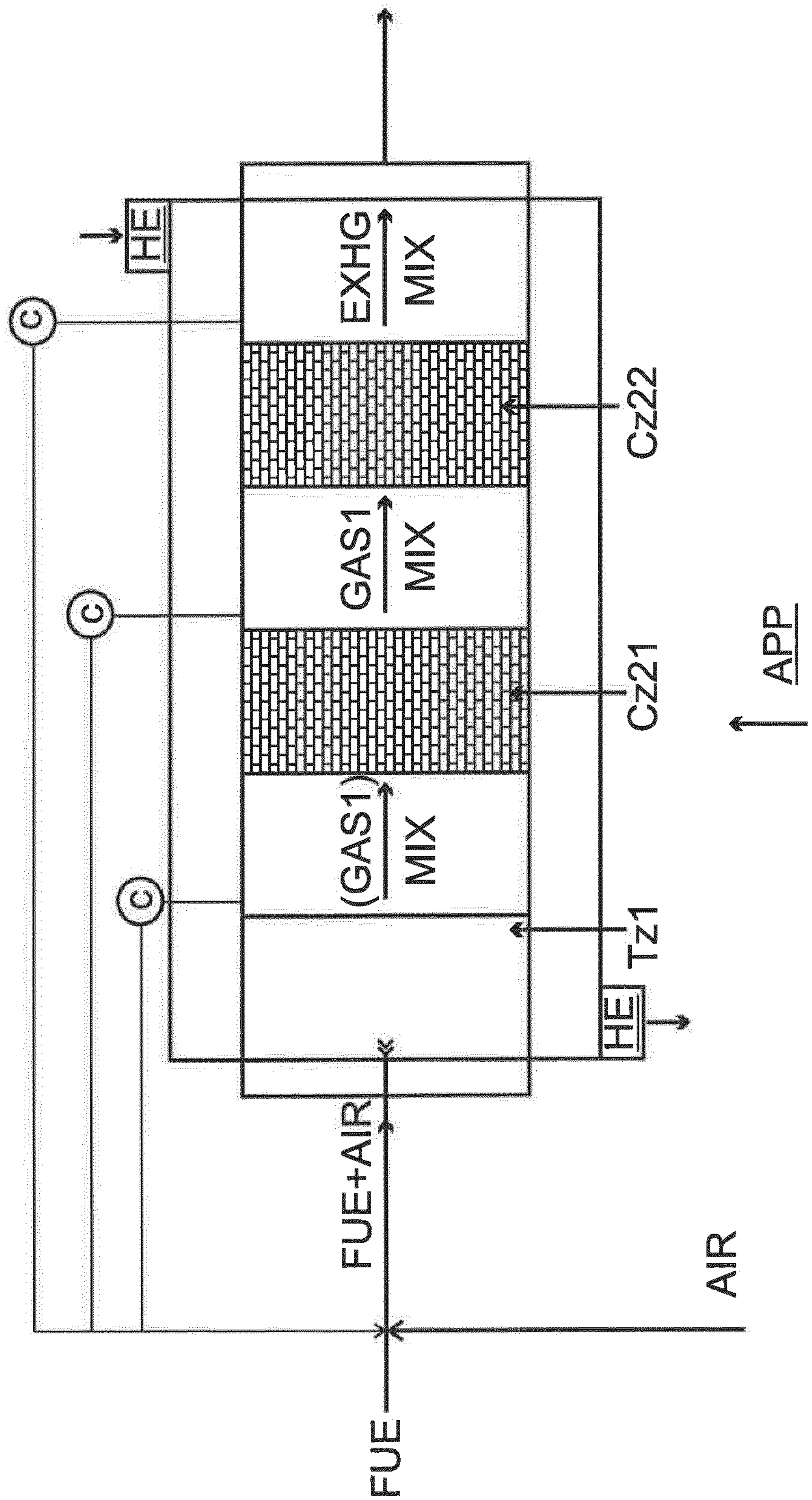
MIX
GAS1
MIX
(GAS1)
MIX
Cz21
Cz12
Cz11
HE
APP
FUE+AIR
AIR
FUE

FIG. 2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EXHG
MIX
Cz22
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GAS1
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Cz21
APP
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(GAS1)
MIX
Tz1
HE
FUE+AIR
AIR
FUE

FIG. 3

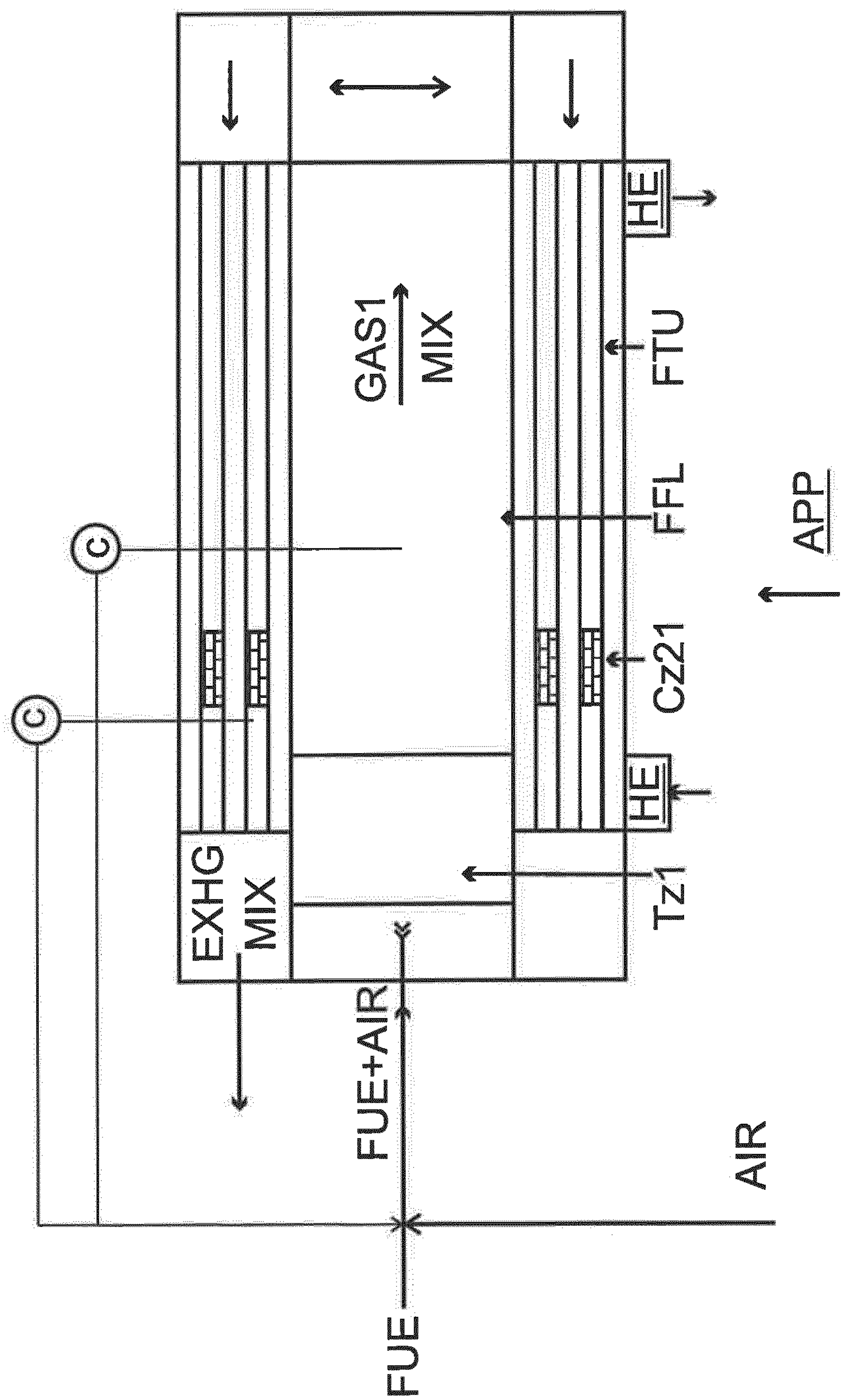

FIG. 4

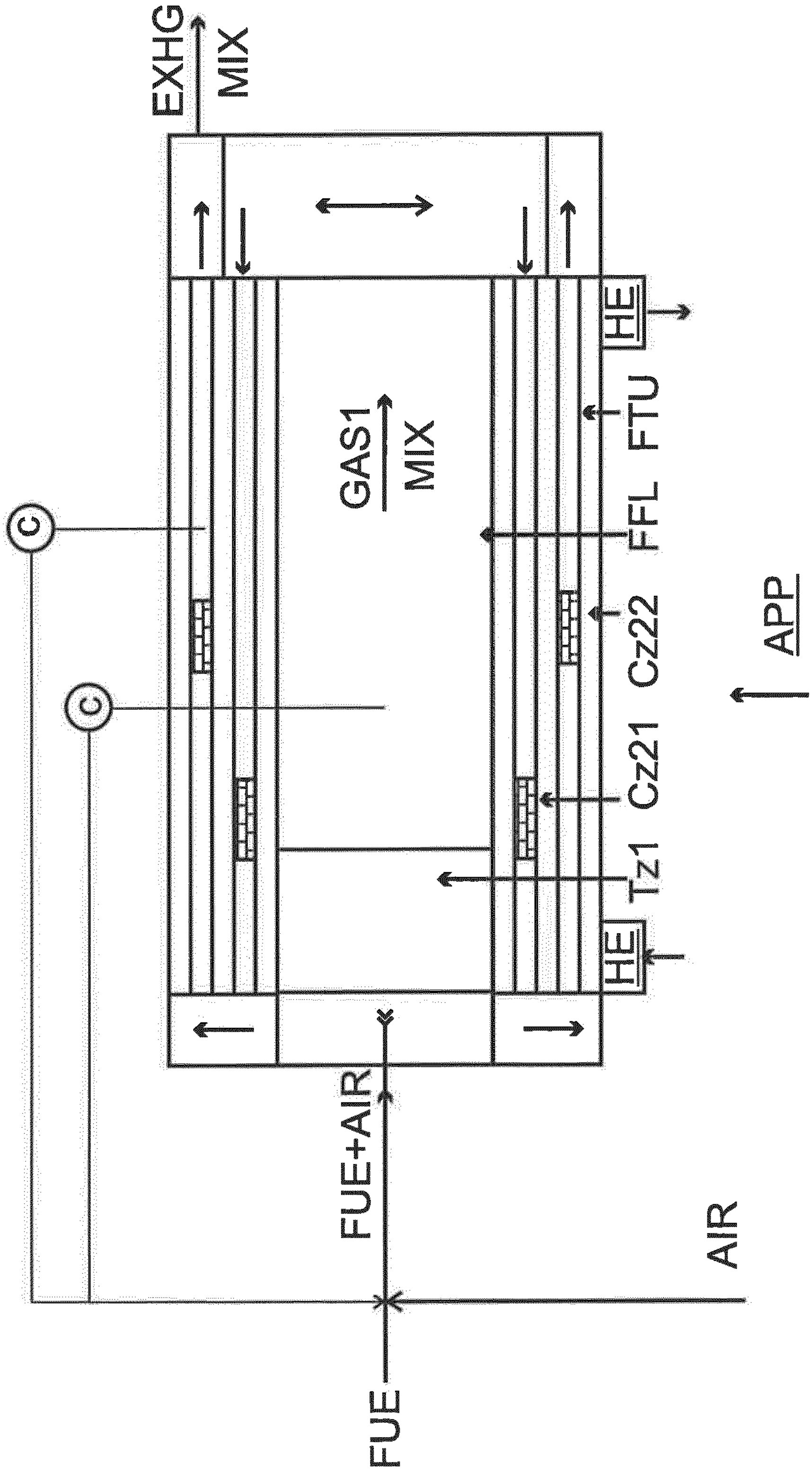
EXHG
MIX
GAS1
MIX
HE
FTU
FFL
Cz22
Cz21
Tz1
HE
C
C
APP
FUE+AIR
AIR
FUE

FIG. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 14 16 1953

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X Y	WO 2010/116035 A1 (FORMIA EMISSIONS CONTROL OY [FI]; LYLYKANGAS REIJO [FI]) 14 October 2010 (2010-10-14) * page 11, line 1 - line 3 * * page 11, line 13 - page 13, line 5 * * claims 1,14-16; figures 1-3 *	1-8,12, 14-18 13	INV. F23N5/00 F23C1/08 F23C6/04 F23C13/06
X	DE 199 62 743 A1 (KOEHNE HEINRICH [DE]) 28 June 2001 (2001-06-28) * page 2, line 49 - page 3, line 18 * * page 4, line 4 - line 29 * * figures 1-3 *	1-3,6, 9-11	
X	US 2012/315586 A1 (GARD VINCENT [US] ET AL) 13 December 2012 (2012-12-13) * page 1, paragraph 3 * * page 3, paragraph 29 - paragraph 31 * * page 4, paragraph 38; figure 2 *	1-4,6,9, 11,15,16	
Y	US 7 399 458 B1 (MARTIN RICHARD R [US] ET AL) 15 July 2008 (2008-07-15) * column 1, line 52 - line 67 * * column 4, line 3 - column 6, line 50 * * figures 1-3 *	13	TECHNICAL FIELDS SEARCHED (IPC) F23N F23C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	3 June 2014	Gavriliu, Costin

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03-06-2014

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010116035 A1	14-10-2010	CN 202902267 U	24-04-2013
		EP 2417390 A1	15-02-2012
		FI 8492 U1	27-10-2009
		US 2012040295 A1	16-02-2012
		WO 2010116035 A1	14-10-2010
DE 19962743 A1	28-06-2001	NONE	
US 2012315586 A1	13-12-2012	NONE	
US 7399458 B1	15-07-2008	NONE	

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82