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(71) Applicant: **Alfa Laval Corporate AB**
221 00 Lund (SE)

(72) Inventors:
- **MØLGAARD, Søren**
  9530 STØVRING (DK)
- **MADSEN, Max**
  9000 AALBORG (DK)

(74) Representative: **Alfa Laval Attorneys**
Alfa Laval Corporate AB
Group Patent
P.O. Box 73
221 00 Lund (SE)

(54) GAS COMBUSTION SYSTEM FOR AMMONIA

(57) A gas combustion arrangement (100) and method for combusting ammonia originating from an ammonia handling system of a marine vessel is provided. The arrangement comprises a combustion chamber (110) comprising a combustion zone (112) and a dilution zone (114), a primary burner (120) configured to combust a primary fuel feed, comprising the ammonia, in the combustion zone, an air supply system (130) configured to provide a combustion air flow to the primary burner and a dilution air flow to the dilution zone, and a secondary burner (140) configured to combust a secondary fuel feed to provide a support flame supporting the combustion of the primary fuel feed.

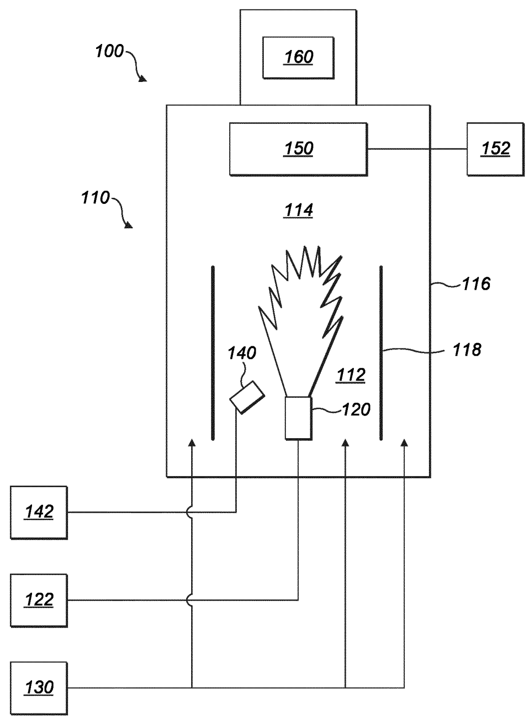

FIG. 1

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Description

Technical field

[0001] The present disclosure relates to gas combustion arrangements and methods for combusting ammonia. More particularly, the disclosure pertains to systems and techniques for combusting ammonia originating from ammonia handling systems of marine vessels, including fuel tanks.

Background

[0002] Marine vessels have traditionally relied on fossil fuels for propulsion and power generation. However, growing environmental concerns and regulatory pressures have led to increased interest in alternative fuel sources.

[0003] Among these alternatives, ammonia is particularly promising due to its carbon-free composition, which helps eliminating carbon dioxide emissions. However, the storage and handling of ammonia present challenges, such as handling boil-off gas produced as ammonia evaporates due to ambient heat absorption. Additionally, ammonia poses significant safety risks, as exposure to high concentrations can be life threatening. Therefore, it is crucial to ensure proper handling of the boil-off gas as well as a complete evacuation of ammonia from the ammonia handling systems during planned shutdowns, inspections, and maintenance.

[0004] One approach would be to combust the released ammonia using a gas combustion system. However, it is challenging to design combustion systems that are capable of handling varying concentrations and flow rates of ammonia, particularly during evacuation and purging in preparation for planned maintenance.

[0005] There is therefore a need for improved gas combustion arrangements and methods for safely and efficiently combusting ammonia originating from the handling systems of marine vessels.

Summary

[0006] It is an object of the present disclosure to provide a technology that addresses at least some of the above concerns.

[0007] According to a first aspect, there is provided a gas combustion arrangement for combusting ammonia from a marine vessel's ammonia handling system. The gas combustion arrangement comprises a combustion chamber with a combustion zone and a dilution zone, a primary burner configured to combust a primary fuel feed, comprising the ammonia, in the combustion zone, and an air supply system configured to provide a combustion air flow to the primary burner and a dilution air flow to the dilution zone. Additionally, the gas combustion arrangement comprises a secondary burner configured to combust a secondary fuel feed to provide a support flame supporting the combustion of the primary fuel feed.

[0008] According to a second aspect, there is provided a method for combusting ammonia, which originates an ammonia handling system of a marine vessel, in a combustion zone of a combustion chamber. The method comprises providing a primary fuel feed, comprising the ammonia, to a primary burner, providing a combustion air flow to the primary burner, and combusting, by the primary burner, the primary fuel feed. Additionally, the method comprises providing a dilution air flow to a dilution zone of the combustion chamber and operating a support flame system in at least one of an active mode and an inactive mode, wherein the support flame system in the active mode combusts secondary fuel feed to generate a support flame supporting the combustion of the primary fuel feed.

[0009] Ammonia is typically stored in liquefied form at -33°C or lower, and as it absorbs ambient heat, boil-off gas is produced. To avoid excessive pressure buildup in the storage tank, the boil-off gas may be directed to the gas combustion arrangement for combustion.

[0010] The gas combustion arrangement may also be configured to combust ammonia released during a so-called tank warming process, in which a fuel tank is evacuated from ammonia in preparation for inspection, or service. This process typically includes emptying the tanks of liquid ammonia and injecting a purge gas to force out remaining ammonia vapours while gradually heating the tank. The gas mixture released during this process may be challenging to combust due to its fluctuating ammonia concentrations. Initially, the escaping gas may consist of nearly 100% ammonia, but as the process continues, the concentration drops towards 0%, with the gas eventually consisting entirely of purge gas.

[0011] Ammonia may be difficult to combust at low concentrations due to its relatively narrow flammability range, typically between 15% and 28%. When ammonia concentrations fall below 15%, combustion may be unsustainable as the mixture becomes too diluted to ignite.

[0012] To address this issue, the gas combustion arrangement features a secondary burner, which is configured to combust a secondary fuel feed. This secondary burner provides a support flame that sustains the combustion of ammonia and serves as an ignition source. The system can be operated in different modes, with the secondary burner either active, producing a support flame, or inactive. This flexible operation allows the support flame to be deployed as needed, such as during low ammonia concentrations, or continuously if required. Beneficially, the present gas combustion arrangement may be employed to handle both boil-off gas as well as ammonia vapours of varying concentrations generated during tank warming.

[0013] The secondary fuel feed, which is used to provide a support flame, may comprise an ammonia-based fuel. In some examples, the primary fuel feed and the secondary fuel feed may be provided from the same fuel storage, such as the fuel tank. Using an ammonia-based fuel for the secondary fuel feed allows for a more streamlined fuel storage and distribution system on the marine vessel, reducing the number of different fuel types that need to be stored and managed onboard. It will however be appreciated that the secondary fuel may comprise other fuels than ammonia. In some examples, the secondary fuel feed may include a fuel based on methane, methanol, liquid hydrocarbons, or hydrogen.

[0014] In some configurations, the air supply system may draw air for both the combustion air flow and the dilution air flow from a common air source. This may contribute to a more streamlined design, reducing the number of separate air intake components required. In other configurations, the air supply system may draw air for the combustion air flow and air for the dilution air flow from separate air sources, potentially allowing for a more precise control of the respective air flows.

[0015] In some examples, the air supply system may be configured to control the combustion air flow and the dilution air flow independently of each other. The separate dilution and combustion air flows enables precise temperature control within the combustion chamber and allows for fine-tuning of the combustion process, potentially leading to improved combustion efficiency. Additionally, the ability to manage temperature precisely may contribute to better emissions control.

[0016] The gas combustion arrangement may include an oxidation catalyst designed to remove residual ammonia from the combustion gases generated by the combustion of the primary fuel feed. This may help reducing ammonia slip further, should any unburnt ammonia remain after the combustion. In configurations where the oxidation catalyst is present, the air supply system may introduce the dilution air flow into the combustion chamber at a position between the combustion zone and the oxidation catalyst. The dilation air flow may be used to control the temperature at the oxidation catalyst and allow it to operate under more optimal temperature conditions.

[0017] Additionally, the arrangement may incorporate a reduction catalyst to remove nitrogen oxides from the combustion gases produced by the primary fuel feed combustion. In cases where a reduction catalyst is included, the arrangement may also feature a reduction agent supply system that provides a reduction agent, such as ammonia, to the reduction catalyst. The reduction catalyst may be arranged upstream of the oxidation catalyst to allow the oxidation catalyst to take care of unused reduction agent.

[0018] The support flame may be used continuously during the operation of the gas combustion arrangement, or selectively when needed. The support flame system may be activated or inactivated manually, by operator intervention, or automatically based on one or more monitored process parameters. In some examples, a sensor system may be provided to generate sensor data indicative of process parameters such as ammonia concentration in the primary fuel feed, ammonia slip (i.e., residual ammonia in the exhaust gas), and combustion temperature.

[0019] In some examples, the temperature in the combustion chamber, such as the combustion zone or the dilution zone, may be determined. The support flame system may be inactive for temperatures exceeding a predetermined threshold, and active when the temperature is at or below this threshold. Additionally, the support flame system may be operated in the active mode during an ignition phase of the primary burner.

[0020] In some examples, the ammonia concentration in the primary fuel feed may be determined and the support flame system operated in the inactive mode when the ammonia concentration exceeds a predetermined threshold, and in the active mode when the concentration is at or below this threshold.

[0021] Furthermore, the concentration of residual ammonia in the exhaust gases produced by the combustion of the primary fuel feed may be determined. The support flame system may be operated in the inactive mode when the residual ammonia concentration is at or below a predetermined threshold, and in the active mode when it exceeds this threshold.

[0022] The dilution air flow may be controlled based on the concentration of residual ammonia in the exhaust gases generated by the combustion of the primary fuel feed. This allows for adjustment of the dilution process in response to the amount of unconsumed ammonia present in the exhaust.

[0023] In some implementations, the exhaust gases may be passed through an oxidation catalyst to remove residual ammonia from the exhaust gases. The dilution air flow may be controlled based on the temperature of the exhaust gases as they pass through the oxidation catalyst. This approach allows for optimization of the dilution process in relation to the catalytic oxidation of residual ammonia.

[0024] Further features and advantages of the invention will become apparent from the following description of preferred embodiments, given by way of example only, which is made with reference to the accompanying drawings.

Brief Description of the Drawings

[0025] Various aspects and examples of the present disclosure will now be described with reference to the accompanying drawings:

Figure 1 is a side view of a gas combustion arrangement for combusting ammonia on a marine vessel.

Figure 2 is a flow diagram illustrating a method for combusting ammonia originating from an ammonia handling system of a marine vessel.

Figure 3 is a schematic diagram showing a gas combustion arrangement according to an example of the present disclosure.

Figure 4 is a flow diagram illustrating a method for combusting ammonia during a tank warming process.

Detailed Description

[0026] Figure 1 shows a gas combustion arrangement 100, or gas combustion unit, according to an example of the present disclosure. The gas combustion arrangement 100 is designed to combust ammonia originating from an ammonia handling system of a marine vessel, such as a cargo ship, a passenger ship, or a naval and defence vessel. The main functions of the gas combustion arrangement 100 may typically be to manage boil-off gases from fuel storage and to handle ammonia vapour and purge gas during a tank warming process, in which fuel tanks and auxiliary systems, such as piping systems, are evacuated in preparation for inspection, service, and maintenance

[0027] The gas combustion arrangement 100 comprises a combustion chamber 110, which may be divided into two zones: a combustion zone 112 and a dilution zone 114. The combustion zone 112 is where the combustion of the primary fuel feed takes place. The dilution zone 114 is arranged downstream of the combustion zone 112, and it is in this zone that a dilution air flow may be added to reduce the temperature of the exhaust gases and dilute the slip of undesired components.

[0028] The gas combustion arrangement 100 comprises a primary burner 120, which is configured to combust a primary fuel feed, comprising ammonia, in the combustion zone 112. The primary fuel feed may be supplied to the primary burner 120 by means of a primary fuel supply system 122, which may be connected to a fuel handling system, such as the fuel tanks, of the marine vessel. The primary fuel supply system 122 may include pumps, valves, and heaters for preparing the primary fuel feed for combustion.

[0029] An air supply system 130 is provided to supply a combustion air flow to the primary burner 120 and the dilution air flow to the dilution zone 114. The air supply system 130 may be configured to draw air for both the combustion air flow and the dilution air flow from a common air source. In alternative examples, the air supply system 130 may be arranged to draw air from separate air sources.

[0030] The gas combustion arrangement 100 also includes a secondary burner 140, which is configured to combust a secondary fuel feed to generate a support flame. The support flame may be used to ignite and/or support the combustion of the primary fuel feed. This may be particularly beneficial in cases where the primary fuel feed comprises a relatively low ammonia concentration.

[0031] The secondary fuel may be provided by a secondary fuel supply 142, which may feed the secondary burner 140 with an ammonia-based fuel or, in some examples, a fuel based on methane, methanol, liquid hydrocarbons, or hydrogen.

[0032] The combustion chamber 110 may comprise a double-wall structure for enhancing thermal management and prevent overheating of the gas combustion arrangement 100. The double-wall structure comprises an inner wall 118 and an outer wall 116, arranged to form a space between them through which the dilution air flow may be directed to dissipate heat. Specifically, the combustion zone 112 may be realised as a smaller cylinder 116 arranged concentrically within a larger, outer cylinder 118, forming an annular air flow channel between the two. The dilution air flow may pass through this channel to absorb heat from the inner wall 118, which is exposed to the high temperatures generated during combustion in the combustion zone 112 and maintain the outer wall 116 at a lower temperature.

[0033] The exhaust gases and dilution air flow may proceed to the dilution zone 114 of the gas combustion chamber 110, where the exhaust gases may be diluted by the dilution air. As will be discussed in further detail below, the exhaust gases may then pass through one or more catalysts 150, 160 for further treatment.

[0034] To further process the combustion gases, the gas combustion arrangement 100 may include a reduction catalyst 150 configured to remove nitrogen oxides from the combustion gases generated by the combustion of the primary fuel feed. A reduction agent supply system 152 can be provided to supply a reduction agent, comprising, e.g., ammonia, to the catalyst 150. Additionally, an oxidation catalyst 160 may be included to remove residual ammonia from the combustion gases, including unused ammonia provided by the reduction agent supply system 152. As illustrated in the present figure, the oxidation catalyst 160 may be arranged downstream of the reduction catalyst 150.

[0035] The dilution air flow may be added to the combustion gases at a position upstream of the catalyst(s) 150, 160 so as to allow the temperature of the gases passing through the catalyst(s) 150, 160 to be regulated.

[0036] The oxidation catalyst 160 may, for example, comprise a platinum group metal, including one or more of platinum, palladium, rhodium, ruthenium, iridium, and osmium. Beneficially, the platinum group metals exhibit a relatively high activity for the oxidation of ammonia and a relatively low activity of the oxidation of nitrogen oxides. Other possible catalysts include copper oxide, manganese oxide, and iron oxide. The operating temperature of the oxidation catalyst 160 may typically range between 300°C and 400°C. It may therefore be desirable to introduce the dilution air flow before the combustion gases reach the catalyst.

[0037] The reduction catalyst 150 may, for example, form part of a selective catalytic reduction (SCR) cleaning arrangement, or SCR unit, which may be provided to further reduce NOx emission from the combustion gases. The SCR cleaning arrangement may be configured to add an SCR agent, such as anhydrous ammonia, aqueous ammonia, or a urea solution to the stream of exhaust gas. The SCR agent may be provided by the reduction agent supply system 152 mentioned above.

The mixture is reacted onto a catalyst bed, which typically comprises various porous ceramic materials, such as titanium oxide, supporting an active catalytic component of a base metal such as vanadium, molybdenum, and tungsten. The reaction typically has an optimal temperature range between 360°C and 450°C but can operate at lower temperatures, such as down to about 280°C, with longer residence times. Thus, to achieve a suitable temperature of the exhaust gas, the dilution air flow may be regulated accordingly.

[0038] The dilution zone 114 thus allows for better control of temperatures and residence times in the combustion chamber 110. This temperature control may help reduce the formation of nitrogen oxides and other pollutants. Additionally, it may improve the efficiency of catalytic processes by maintaining optimal working temperatures for catalysts.

[0039] Figure 2 is a flow diagram depicting a method for combusting ammonia, which relates to the features shown in figure 1. The method may be performed in the gas combustion arrangement 100 shown in figure 1 and provides a process for handling the combustion of ammonia originating, for example, from boil-off gas or a tank warming process of a vessel.

[0040] The method 200 begins with block 202, which represents a step of providing a primary fuel feed comprising ammonia. The primary fuel feed is supplied to the primary burner 120 in the combustion chamber 112 by a fuel supply system 122, which may comprise a series of components such as pumps, compressors, control valves, heaters, and fuel lines.

[0041] Following this block, block 204 indicates the provision of a combustion air flow to the primary burner 120. The combustion air flow may be supplied by an air supply system 130, as depicted in figure 1.

[0042] Block 206 represent the combustion of the primary fuel feed in the primary burner 120. This combustion takes place in the combustion zone 112 of the combustion chamber 110. Simultaneously, as shown in block 208, a dilution air flow may be provided to the dilution zone 114. This dilution air flow may be supplied to the dilution zone 114 by means of the air supply system 130.

[0043] The air supply system 130 may be configured to control the combustion air flow and the dilution air flow independently, allowing for separate regulation of the combustion process and the temperature in the dilution zone 114. The combustion air flow can be adjusted based on the flow rate and ammonia concentration of the primary fuel feed to achieve an optimal fuel-air ratio for efficient combustion. Meanwhile, the dilution air flow may be regulated according to the desired exhaust gas temperature, which may be determined by the operating range of catalysts, such as oxidation or reduction catalysts, in the system. In some examples, the combustion air flow and the dilution air flow may be provided by separate flow paths, which may be regulated by separate air flow systems. In other examples, the combustion air flow and the dilution air flow may be provided from a common air flow which is split into the combustion air flow and the dilution air flow. The splitting ratio may be fixed or variable, depending on the implementation.

[0044] A decision point in the process is represented by decision block 210, which determines the mode of operation for the support flame system. The support flame may be selectively used, such as at low ammonia concentrations in the primary fuel feed, or continuously during the combustion process. This decision leads to two possible paths: active mode 212 in which a support flame is produced to support the combustion of the primary feed, and inactive mode 214 in which no support flame is generated.

[0045] The support flame system may operate in inactive mode 214 when the ammonia concentration is high enough to ignite and sustain efficient combustion. Efficient combustion can be detected by, for example, measuring the temperature in the combustion chamber or the ammonia slip, i.e., the concentration of residual ammonia in the exhaust gases. A high temperature, or low concentrations of residual ammonia, indicated efficient combustion (i.e., high ammonia concentration) while low temperature, or high concentration of residual ammonia in the exhaust gases, indicates inefficient or non-existing combustion (i.e., low ammonia concentration in the primary fuel feed).

[0046] The method described in figure 2 provides a flexible approach to combusting ammonia, allowing for efficient operation across varying ammonia concentrations. By selectively activating or deactivating the support flame system, the method ensures stable and complete combustion of the ammonia-based primary fuel feed.

[0047] Figure 3 illustrates a gas combustion arrangement 100, which may be configured similarly to the gas combustion arrangements discussed above in connection with figures 1 and 2.

[0048] One or more sensors may be provided to monitor the operation of the gas combustion arrangement 100 and provide feedback for controlling the various components and subsystems of the gas combustion arrangement 100. Specifically, sensor feedback can be used to determine in which mode the support flame system is to be operated. In the present example, the gas combustion arrangement 100 comprises a sensor system 170 comprising one or more sensors for monitoring process parameters of the gas combustion and providing feedback to a control unit 180 controlling the operation of the gas combustion arrangement 100.

[0049] As mentioned above, the support flame may be provided to support the combustion of the primary fuel feed at lower ammonia concentrations, for which the ammonia becomes too diluted to ignite and sustain a stable combustion. This may typically occur for ammonia concentrations below 15%. The sensor system 170 may be employed to detect too low ammonia concentrations, either indirectly or directly, as well as unsustainable or inefficient combustion caused by a too low ammonia concentration.

[0050] In one example, the sensor system 170 comprises an ammonia concentration sensor 172 arranged to measure the ammonia concentration in the primary fuel feed. Alternatively, or additionally, the sensor system 170 comprises a temperature sensor 174 arranged to measure the temperature in the combustion chamber 110, such as in the combustion zone 112 or the dilution zone 114. The temperature may be indicative of the efficiency of the combustion and thus the ammonia concentration of the fuel feed being burnt. In further examples, the sensor system 170 comprises an ammonia concentration sensor 176 arranged to measure the ammonia slip in the exhaust gas. Increasing residual ammonia concentrations may indicate that the combustion process is becoming more unstable and inefficient, and that the support flame may be needed to promote the combustion.

[0051] The data provided by one or more of the sensors of the sensor system 170, such as the ammonia concentration sensor(s) 172, 176 and the temperature sensor 174, may be supplied to the control unit 180, which may be arranged to control the operation of the primary burner 120 and the secondary burner 140, the air supply system 130, and the supply of the primary fuel feed. The control unit 180 receives sensor data from the sensor system 170 and controls the operation of the gas combustion arrangement 100 accordingly.

[0052] In particular, the control unit 180 may control the operation of the secondary burner 140. The secondary burner 140 may be activated to provide the support flame for ammonia concentrations being below a certain concentration threshold, such as 15%, or for combustion chamber temperatures being below a certain temperature limit.

[0053] The control unit 180 may also operate the support flame system in the active mode during an ignition phase of the primary burner 120 to assist in the initial combustion process. This can help ensure reliable ignition, particularly when dealing with fuel feeds that may be challenging to ignite under certain conditions, such as low ammonia concentrations.

[0054] In the present example, the air supply system comprises two separate subsystem - a combustion air supply 132 and a dilution air supply 134. The combustion air and the dilution air may hence be provided by means of two separate flow paths, which may be controlled separate from each other. This allows for the supply of combustion air and the supply of dilution air to be optimised for the combustion and the dilution, respectively. In other examples, the combustion air and the dilution air may be provided by a common system or flow path, which may be split into two separate air flows upon entering the combustion chamber. The ratio between the combustion air and the dilution air may be fixed or adjustable, depending on the configuration.

[0055] Figure 4 is a flow chart illustrating a potential use of the gas combustion arrangement 100 during a tank warming process, where ammonia tanks and associated piping systems of a marine vessel are evacuated of ammonia prior to inspection or maintenance.

[0056] In a first step 402 of the depicted method 400, the tank is drained of any remaining liquid ammonia by pumping it out of the tank and redirecting it to the gas combustion arrangement 100 for combustion. At this stage, the primary fuel feed combusted by the primary burner 120 may comprise close to 100% ammonia, and the secondary burner 140 may remain inactive.

[0057] After the liquid ammonia is evacuated, a purge gas (typically an inert gas like nitrogen) is introduced 404 into the tank to begin the warming process. The purge gas displaces the ammonia vapours, forcing them out of the tank. This purging process also gradually heats the tank, as the purge gas is typically at a higher temperature than the cryogenic ammonia. Initially, the vented gas stream may have a high ammonia concentration (up to 100%), but this concentration may gradually decrease as the purge gas continues to flush out the ammonia vapours. The vented gas may be routed to the gas combustion arrangement 100 for combustion by the primary burner 120.

[0058] As the tank warming process progresses, the ammonia concentration may eventually fall below the lower flammability limit, at which point the ammonia becomes too diluted to sustain a stable combustion. To address this, the secondary burner 140 may be activated 406 to produce a support flame, ensuring continued combustion of the vented gas despite the reduced ammonia concentration. The secondary burner 140 may be activated either manually by operator intervention, or automatically by the control unit 180 as discussed above.

[0059] The purge process may continue until the ammonia concentration in the vented gas is negligible, often approaching 0%. At such low concentrations, sustaining combustion may become challenging, even with the support flame. Therefore, in step 408, secondary burner may be shut off. To further ensure compliance with emission standards, the flow of dilution air may be increased in step 410. This additional air may dilute any remaining ammonia passing through the gas combustion arrangement, helping to reduce the ammonia concentration below regulatory limits. In some examples, the maximum allowable limit is set to 25 ppm.

[0060] As mentioned above, the operation of the gas combustion arrangement 100 may be controlled by a controller, or control unit 180, which may be incorporated in the gas combustion arrangement 100 or arranged at another location, physically separate from the gas combustion arrangement 100. The controller 180 may be communicatively connected to the primary burner 120, the primary fuel supply 122, the air supply system 130, the secondary burner 140, the secondary fuel supply 142, and the sensor system 170, as discussed in connection with figure 3. The controller 180 may be arranged to control an operation of one or more of these components of the gas combustion arrangement 100.

[0061] The control unit 180 may generally comprise one or more processors and one or more non-transitory computer-readable media storing first computer executable instructions that, when executed by the one or more processors, cause the gas combustion arrangement 100 to perform at least parts of the actions shown in figures 2 and 4 and described above. Generally, the control unit 180 may comprise circuitry which is configured to implement (using one or more non-transitory computer-readable media) the functionality described herein. Suitable processors for the execution of a program of instructions include, by way of example, both general and special purpose microprocessors, and the sole processor or one of multiple processors or cores, of any kind of computer. The processors can be supplemented by, or incorporated in, ASICs (application-specific integrated circuits). Those skilled in the art will understand that the above-described exemplary embodiments may be implemented in any suitable software, hardware, or firmware configuration or combination thereof. An exemplary hardware platform for implementing the exemplary embodiments may include, for example, an Intel x86 based platform with compatible operating system, a Windows OS, a Mac platform and MAC OS, a mobile device having an operating system such as iOS, Android, etc. In a further example, the exemplary embodiments of the above-described method may be embodied as a program containing lines of code stored on a non-transitory computer readable storage medium that, when compiled, may be executed on a processor or microprocessor.

[0062] Additionally, variations to the disclosed embodiments can be understood and effected by the skilled person in practising the claimed invention, from a study of the drawing, the disclosure, and the appended claims. Moreover, in the drawings and specification, there have been disclosed preferred embodiments and examples of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation. The scope of the invention is set forth in the following claims, in which the word 'comprising' does not exclude other elements or steps, and the indefinite article 'a' or 'an' does not exclude a plurality.

Claims

1. A gas combustion arrangement (100) for combusting ammonia originating from an ammonia handling system of a marine vessel, comprising:

a combustion chamber (110) comprising a combustion zone (112) and a dilution zone (114);
a primary burner (120) configured to combust a primary fuel feed, comprising the ammonia, in the combustion zone;
an air supply system (130) configured to provide a combustion air flow to the primary burner and a dilution air flow to the dilution zone; and
a secondary burner (140) configured to combust a secondary fuel feed to provide a support flame supporting the combustion of the primary fuel feed.

2. The gas combustion arrangement according to claim 1, wherein the secondary fuel feed comprises an ammonia-based fuel.

3. The gas combustion arrangement according to claim 1 or 2, wherein the secondary fuel feed comprises a fuel based on at least one of methane, methanol, liquid hydrocarbons, or hydrogen.

4. The gas combustion arrangement according to any of the preceding claims, wherein the air supply system is configured to draw air for the combustion air flow and the dilution air flow from a common air source.

5. The gas combustion arrangement according to any of claims 1-3, wherein the air supply system is configured to draw air for the combustion air flow and air for the dilution air flow from separate air sources.

6. The gas combustion arrangement according to any of the preceding claims, wherein the air supply system is configured to control the combustion air flow and the dilution air flow independently of each other.

7. The gas combustion arrangement according to any of the preceding claims, further comprising an oxidation catalyst (160) configured to remove residual ammonia from combustion gases generated by the combustion of the primary fuel feed.

8. The gas combustion arrangement according to claim 9, wherein the air supply system is configured to introduce the dilution air flow into the combustion chamber at a position located between the combustion zone and the oxidation catalyst.

9. The gas combustion arrangement according to any of the preceding claims, further comprising a reduction catalyst (150) configured to remove nitrogen oxides from the combustion gases generated by the combustion of the primary fuel feed.

10. The gas combustion arrangement according to claim 9, further comprising a reduction agent supply system (152) configured to provide a reduction agent to the reduction catalyst.

11. A method (200) for combusting ammonia, originating from an ammonia handling system of a marine vessel, in a combustion zone of a combustion chamber, the method comprising:

providing (202) a primary fuel feed, comprising

the ammonia, to a primary burner;
providing (204) a combustion air flow to the primary burner;
combusting (206), by the primary burner, the primary fuel feed;
providing (208) a dilution air flow to a dilution zone of the combustion chamber; and
operating a support flame system in at least one of an active mode (212) and an inactive mode (214), wherein the support flame system in the active mode combusts a secondary fuel feed to generate a support flame supporting the combustion of the primary fuel feed.

12. The method according to claim 11, comprising:

determining a temperature in the combustion chamber;
operating the support flame system in the inactive mode based on the temperature exceeding a predetermined temperature threshold; and
operating the support flame system in the active mode based on the temperature being at or below the predetermined temperature threshold.

13. The method according to claim 11, comprising: operating the support flame system in the active mode during an ignition phase of the primary burner.

14. The method according to claim 11, comprising:

determining an ammonia concentration in the primary fuel feed;
operating the support flame system in the inactive mode based on the ammonia concentration exceeding a predetermined concentration threshold; and
operating the support flame system in the active mode based on the ammonia concentration being at or below the predetermined concentration threshold.

15. The method according to claim 11, comprising:

determining a concentration of residual ammonia in exhaust gases generated by the combustion of the primary fuel feed;
operating the support flame system in the inactive mode based on the concentration of residual ammonia being at or below a predetermined concentration threshold; and
operating the support flame system in the active mode based on the concentration of residual ammonia exceeding the predetermined concentration threshold.

16. The method according to any of claims 11-13, comprising:
controlling the dilution air flow based on a concentration of residual ammonia in exhaust gases generated by the combustion of the primary fuel feed.

17. The method according to any of claims 11-13, comprising:

passing exhaust gases, generated by the combustion of the primary fuel feed, through an oxidation catalyst to remove residual ammonia from the exhaust gases; and
controlling the dilution air flow based on a temperature of the exhaust gases passing through the oxidation catalyst.

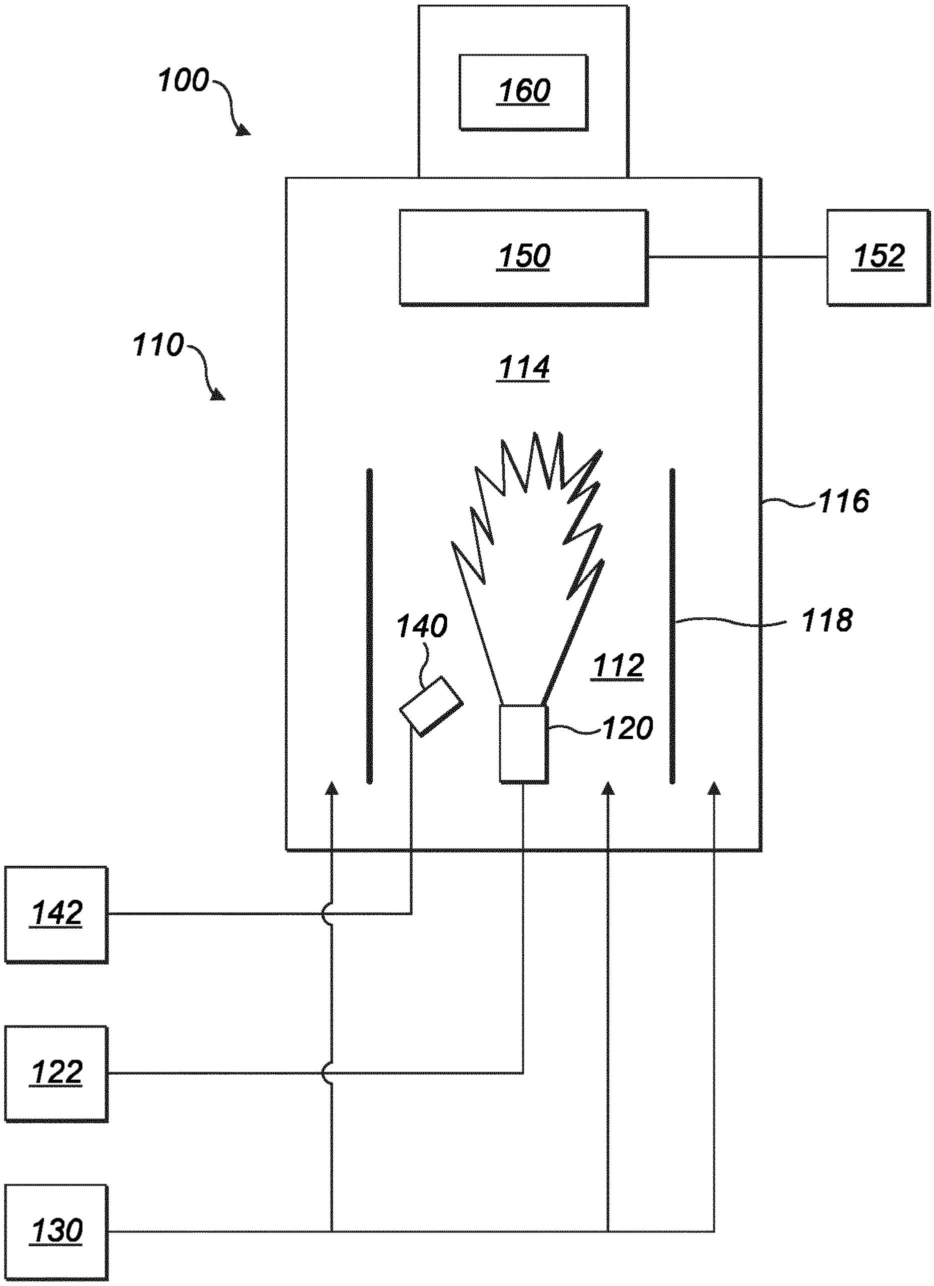

FIG. 1

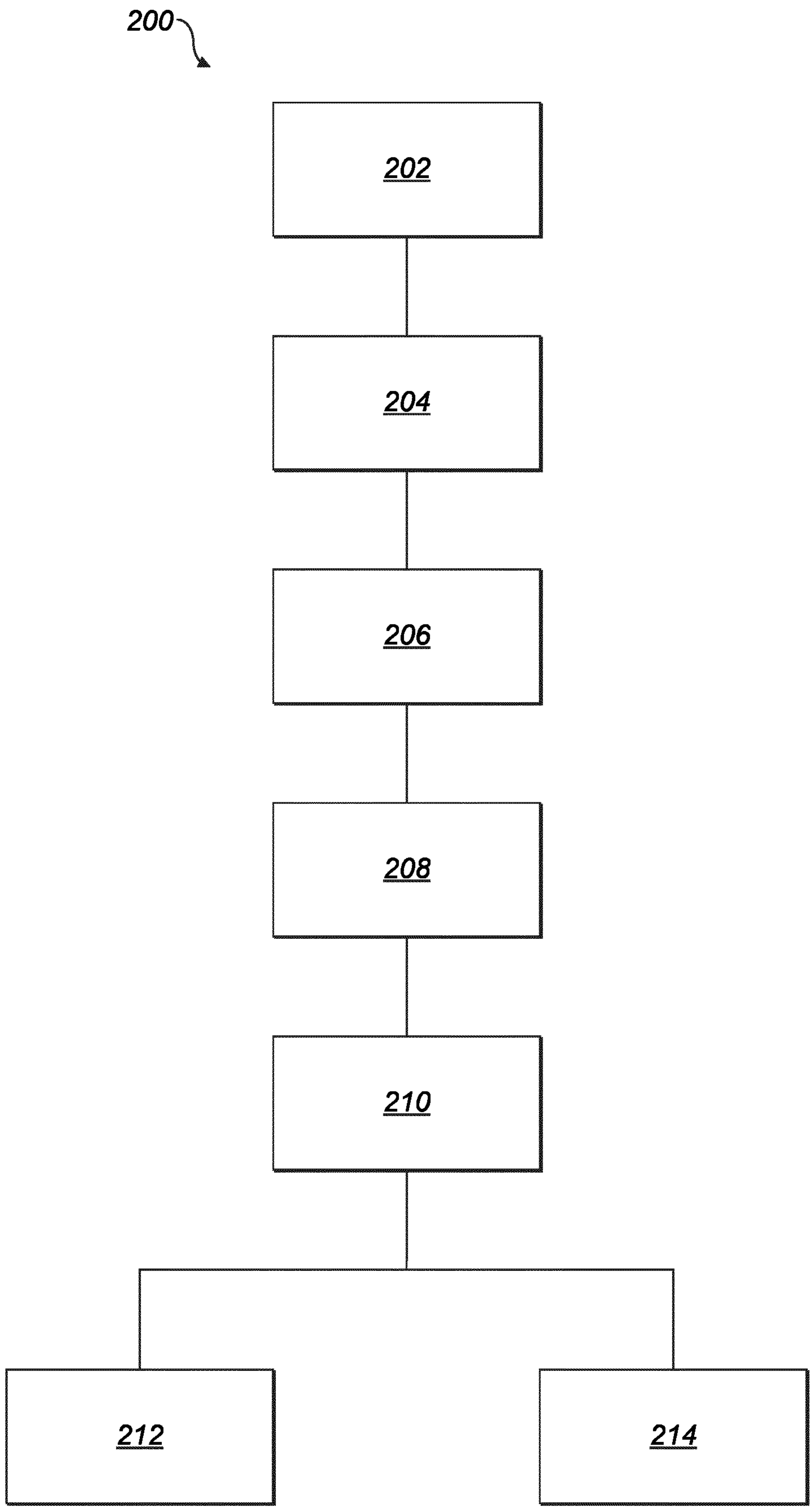

FIG. 2

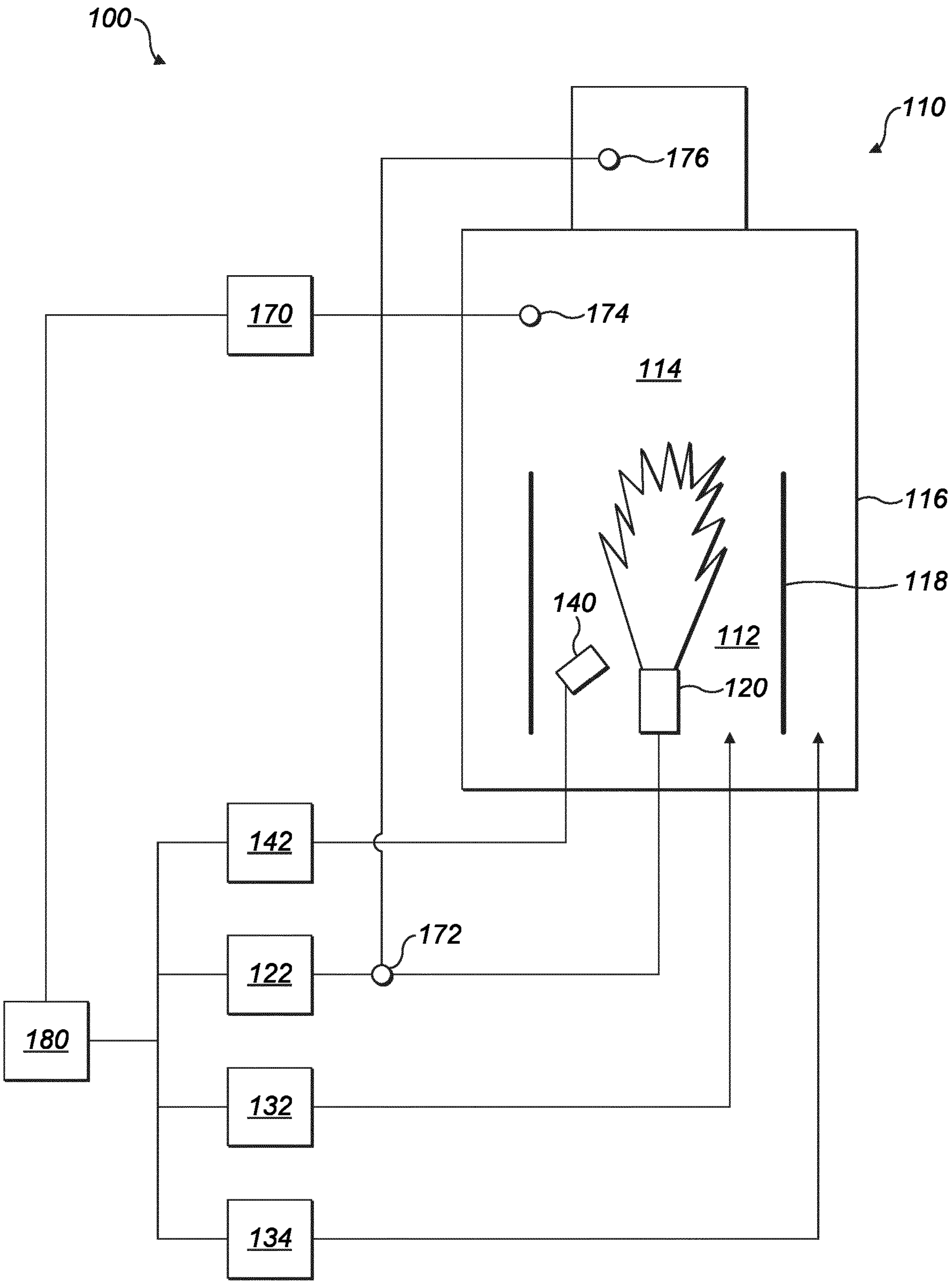
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FIG. 3

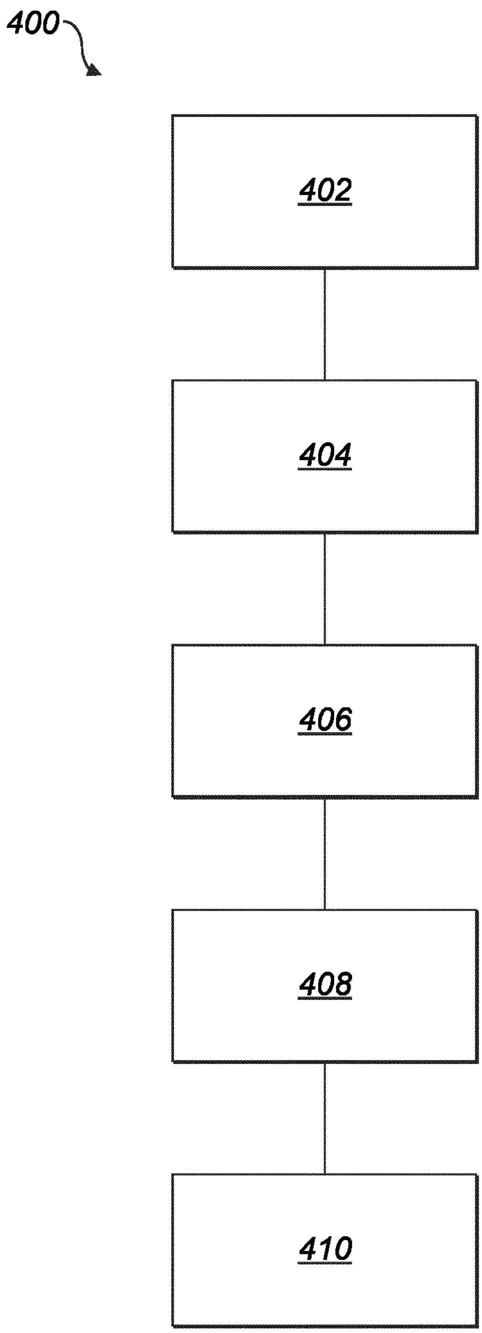

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 24 21 2198

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	EP 4 455 554 A1 (ROSENERGOATOM [RU] ET AL.) 30 October 2024 (2024-10-30) * column 2, paragraph 10 - column 4, paragraph 19 * * figures 1, 2 * -----	1-17	INV. F23D14/26 F23G7/06 F23N5/00
X	CN 118 687 148 A (HEFEI COMPREHENSIVE NATIONAL SCIENCE CENTER ENERGY RES INSTITUTE ANHUI) 24 September 2024 (2024-09-24) * figures 1, 2, and the relating passages of the description * -----	1,2,6,11	
X	US 2023/047390 A1 (LI SHUI-QING [CN] ET AL) 16 February 2023 (2023-02-16) * page 3, paragraph 48 - page 9, paragraph 97 * * figures 1-12 * -----	1,2,11	
A	WO 2023/037643 A1 (CHUGAI RO KOGYO KAISHA LTD [JP]) 16 March 2023 (2023-03-16) * figures 1, 2, and the relating passages of the description * -----	1-17	TECHNICAL FIELDS SEARCHED (IPC) F23D F01N F23C F23G F23J F23N
A	DE 196 30 417 A1 (BASF AG [DE]) 29 January 1998 (1998-01-29) * the whole document * -----	1-17	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	1 April 2025	Rudolf, Andreas

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
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& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 24 21 2198

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01-04-2025

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