

(19)



(11)

EP 4 585 857 A1

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:
16.07.2025 Bulletin 2025/29

(51) International Patent Classification (IPC):
F23N 1/00 (2006.01) **F23N 5/18** (2006.01)
F23N 5/24 (2006.01)

(21) Application number: **24151154.2**

(52) Cooperative Patent Classification (CPC):
F23N 5/184; F23N 1/002; F23N 5/242;
F23C 2201/301; F23K 2900/05004; F23N 2005/185;
F23N 2231/20; F23N 2231/22; F23N 2237/08;
F23N 2239/04

(22) Date of filing: **10.01.2024**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

- **KUZNIAR, Jakub**
31-545 Krakow (PL)
- **SULKOWSKA, Urszula**
31-545 Krakow (PL)
- **VICARI, Lorenzo**
60439 Frankfurt am Main (DE)
- **BOGUCKA, Kaja**
31-545 Krakow (PL)

(71) Applicant: **L'AIR LIQUIDE, SOCIETE ANONYME
POUR L'ETUDE ET
L'EXPLOITATION DES PROCEDES GEORGES
CLAUDE**
75007 Paris (FR)

(74) Representative: **Air Liquide
L'Air Liquide S.A.
Direction de la Propriété Intellectuelle
75, Quai d'Orsay
75321 Paris Cedex 07 (FR)**

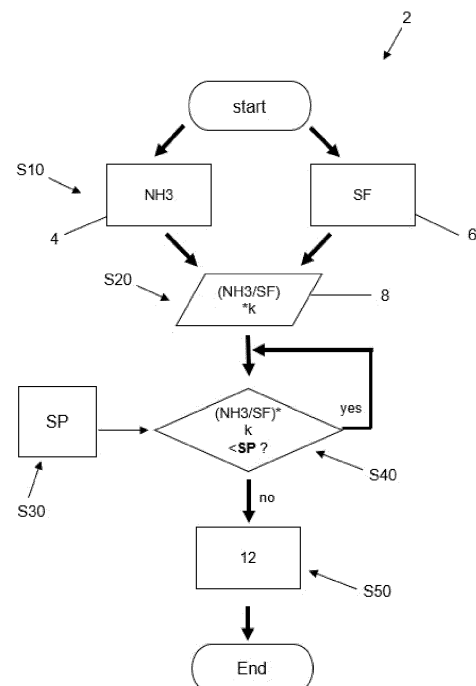
(72) Inventors:
• **ULBER, Dieter**
60439 Frankfurt am Main (DE)

(54) SAFETY GUARD PROCESS FOR A COMBUSTION PROCESS

(57) The invention relates to a safety guard process (2) for a combustion process comprising the combustion of a fuel (4), in particular an ammonia fuel (4), with a stabilizing fuel (6), said safety guard process (2) comprises the following steps of:

- providing flow rate data of the fuel (4), and flow rate data of the stabilizing fuel (6) (S10);
- determining safeguard data (8) based on said flow rate data (NH₃, SF) of said fuels (S20);
- providing threshold data (SP) indicating a stability limit of the safeguard data (S30);
- comparing the safeguard data (8) with the threshold data (SP) (S40); and
- carrying out a security action (12), based on the result of said comparison of the safeguard data (8) with the threshold data (SP) (S50).

Fig. 3

**EP 4 585 857 A1**

Description

[0001] The present invention relates to a safety guard process for a combustion process using a fuel and a stabilizing fuel. The invention also relates to an apparatus configured to perform such a safety guard process.

[0002] Hydrogen is renowned for its lightweight nature and optimal combustion properties as a fuel and its environment-friendliness during its combustion, i.e., no emission of any carbon dioxide (CO₂), particulate or sulfur. This makes hydrogen a vector for the energy transition.

[0003] However, transporting pure hydrogen gas is a complex challenge for safety reasons. To this end, ammonia (NH₃), containing three atoms of hydrogen and facilitating the transport of hydrogen, is a good alternative as a fuel to pure hydrogen gas (H₂).

[0004] Nevertheless, ammonia has poor combustion properties, such as small explosion limits window, high ignition temperature, and slow kinetics.

[0005] For example, for combustion applications of ammonia in industrial furnaces, increasing the ammonia concentration in a fuel leads to instability of the flame during the fuel combustion and in some cases even loss of combustion. Such instability of the flame may jeopardize the smooth operation of the industrial furnace. Therefore, ammonia, as well as other unstable fuels, require a stabilizing fuel, such as hydrogen, to be combusted in a stable manner.

[0006] In order to detect the instability of said flame, a conventional flame detecting device can be used. However, the measured deviation of such flame detecting device is caused by its surrounding environment (i.e., high temperature conditions) of the industrial furnace. Moreover, the flame detection of such a device depends on several parameters, such as a fuel composition and these flame detecting devices are not adapted for the combustion of a fuel, such as ammonia, with a stabilizing fuel. In addition, each fuel has different flame radiation pattern which has to be calibrated by a flame detecting device, which has the effect of lowering the reliability of the flame detecting device.

[0007] Therefore, there is a need to counterbalance these issues and, in particular to avoid the loss of combustion of the fuel.

[0008] For this purpose, the invention relates to a safety guard process for a combustion process comprising the combustion of a fuel, in particular an ammonia fuel, with a stabilizing fuel, said safety guard process comprises the following steps of:

- providing flow rate data of the fuel, and flow rate data of the stabilizing fuel;
- determining safeguard data based on said flow rate data of the fuel and of the stabilizing fuel;

- providing threshold data indicating a stability limit of the safeguard data;
- comparing the safeguard data with the threshold data; and
- carrying out a security action, based on the result of said comparison of the safeguard data with the threshold data.

[0009] The flow rate data of the fuel is related to a flow rate of the fuel (or fuel flow rate) and the flow rate data of the stabilizing fuel is related to a flow rate of the stabilizing fuel (or stabilizing fuel flow rate). The flow rate data of the fuel can be for example a heating value of the fuel flow rate sent to a burner and the flow rate data of the stabilizing fuel can be for example a heating value of the stabilizing fuel flow rate sent to said burner.

[0010] Thanks to the invention, a security action to control the combustion process of the fuel and the stabilizing fuel, is carried out, based on the flow rate data of said fuels.

[0011] This circumvents the dependence on parameters, for example the temperature of the flame resulting from the combustion of said fuels, which may deviate or may introduce bias into the flame detection. Thus, this avoids delaying or anticipating the ideal moment at which the security action should be carried out.

[0012] Put differently, thanks to the invention, the ideal moment at which the security action should be carried out, is precisely determined without needing to change setting parameters of the flame detection, or to change a flame detecting device itself, each time the combustion of said fuels influences the flame detection. Therefore, the flame detection and the security action to be carried out are simple, fast and cost-effective compared with a classical flame detection using the flame detection device.

[0013] The invention may comprise at least one of the following features, taken independently or in combination.

[0014] According to one embodiment, the safeguard data are determined based on a calculation involving a flow rate data of the fuel, and flow rate data of the stabilizing fuel as variables.

[0015] According to one embodiment, the stability limit comprises a range of the safeguard data or new safeguard data for which the combustion process is running in accordance to a stable combustion criteria.

[0016] Therefore, when the status of the combustion of said fuels is likely to compromise the stability of the combustion process (the stable combustion criteria is not met), in view of the safeguard data, security measures are taken. For example, this may be a situation in which the ammonia fuel is in some excess compared with the stabilizing fuel, for example hydrogen gas, such that the combustion of the ammonia fuel leads to stability issues.

[0017] According to one embodiment, the security ac-

tion comprises triggering a visual alarm or a sound alarm.

[0018] Advantageously, the threshold data can be numerical values of a parameter, or a ratio or a product of these numerical values. Advantageously, the security action can be carried out if the safeguard data are determined to be outside of the stability limit of the safeguard data based on the result of said comparison.

[0019] According to one embodiment, the security action comprises:

- at least a control system action comprising changing a parameter of the combustion process to bring back the safeguard data within its stability limit.

[0020] According to one embodiment, the security action comprises:

- a safety system action comprising stopping the combustion process.

[0021] In one embodiment, the security action comprises setting a stabilization deadline before performing the following steps:

- providing a new flow rate data of the fuel, in particular of an ammonia fuel, and a new flow rate data of the stabilizing fuel and determining a new safeguard data based on said new flow rate data of the fuel and of the stabilizing fuel;
- comparing the new safeguard data with the threshold data.

[0022] This way, waiting the stabilization deadline allows a time lapse between a temporary anomaly of the flow rate data of said fuels, and the control system action so as to let the flow rate data of said fuels to be stabilized by its own.

[0023] According to one embodiment, the control system action is performed after the expiry of the stabilization deadline, in particular based on the result of the comparison of the new safeguard data with the control threshold.

[0024] According to one embodiment, the control system action, in particular, changing a parameter of the combustion process, comprises adjusting the fuel flow rate and/or the stabilizing fuel flow rate such that the safeguard data are brought back within its control stability limit.

[0025] In particular, the threshold data comprises a control threshold, and the control system action is carried out based on the result of the comparison of the safeguard data with the control threshold.

[0026] In one embodiment, the control system action, in particular, adjusting the fuel flow rate and/or the stabilizing fuel flow rate, comprises keeping constant the fuel flow rate while increasing the stabilizing fuel flow rate.

[0027] Alternatively, the control system action, in particular, adjusting the fuel flow rate and/or the stabilizing fuel flow rate, comprises keeping constant the stabilizing

fuel flow rate while decreasing the fuel flow rate.

[0028] Alternatively, the control system action, in particular, adjusting the fuel flow rate and/or the stabilizing fuel flow rate, comprises decreasing the fuel flow rate while increasing the stabilizing fuel flow rate.

[0029] Thus, the safeguard data can be adjusted with a steeper variation.

[0030] According to one embodiment, the threshold data further comprises a safety threshold SP1 indicating a safety limit of the safeguard data, the stability limit being within said safety limit and the safety system action is performed based on the result of said comparison of the safeguard data with the safety threshold SP1.

[0031] According to one embodiment, the safety limit comprises a range of the safeguard data or new safeguard data for which the combustion process is running in accordance to safe combustion criteria.

[0032] Therefore, when the status of the combustion of said fuels is likely to compromise the safety of the combustion process, in view of the safeguard data, i.e. the safe combustion criteria is not met, the combustion process is stopped or a plant in which the combustion process is being carried out is shut down.

[0033] For example, this may be a situation in which the ammonia fuel is in a large excess compared with a stabilizing fuel, for example hydrogen gas, such that the combustion of the ammonia fuel leads to safety issues.

[0034] According to one embodiment, the control system action and the safety system action are performed independently, in particular independently and simultaneously.

[0035] According to one embodiment, the control system action is carried out before the safety system action.

[0036] In one embodiment, the new safeguard data is determined to be outside of a stability limit of said new safeguard data based on the result of the comparison between the new safeguard data with the threshold data and the process comprises performing the control system action and/or the safety system action.

[0037] In particular, the new safeguard data is determined to be outside of a stability limit of said new safeguard data based on the result of the comparison of the new safeguard data with the control threshold SP2 and the safety guard process comprises performing the control system action.

[0038] In particular, the new safeguard data is determined to be outside of a safety limit of said new safeguard data based on the result of the comparison of the new safeguard data with the safety threshold SP1 and the safety guard process comprises performing the safety system action.

[0039] In one embodiment, the safety guard process comprises setting a control deadline during which the control system action is performed and if the safeguard data is determined to be still outside of the stability limit of the safeguard data after said control deadline based on the result of the comparison between the safeguard data

with the control threshold SP2, the process comprises performing the safety system action.

[0040] This way, the safety system action can be carried out when the control system action alone is not sufficient to let the safeguard data to be within the stability limit of said safeguard data.

[0041] In one embodiment, the safeguard data are determined based on a ratio between the fuel flow rate and the stabilizing fuel flow rate.

[0042] Preferably, the safeguard data are determined based on a ratio of an ammonia fuel flow rate NH₃, to the stabilizing fuel flow rate, SF.

[0043] In one embodiment, the safeguard data are determined based on said ratio multiplied by a constant k.

[0044] In one embodiment, the flow rate data of the fuel and/or the flow rate data of the stabilizing fuel are provided by a measurement of the fuel flow rate and/or a measurement of the stabilizing fuel flow rate.

[0045] Alternatively, the flow rate data of the fuel and/or the flow rate data of the stabilizing fuel may be provided by a measurement of a pressure drop of the fuel flow over a fuel flow orifice and/or a measurement of a pressure drop of the stabilizing fuel flow over a fuel flow orifice.

[0046] In a further alternative, the flow rate data of the fuel and/or the flow rate data of the stabilizing fuel may be provided by other fuel gas analyzers, optionally with internal calculation of heating values, such as calorific value instruments.

[0047] In one embodiment, the safety guard process comprises comparing the safeguard data with the threshold data, in particular with the control threshold SP2, as long as the safeguard data are within the stability limit of said threshold data.

[0048] In one embodiment, the safety guard process, in particular, comparing the safeguard data with the threshold data, comprises:

- comparing the absolute value of a difference between a numerical value of the safeguard data and a numerical value of the threshold data, with a stability tolerance value.

[0049] In particular, the safety guard process comprises carrying out said security action, based on the result of said comparison of the absolute value with the stability tolerance value.

[0050] In one embodiment, the safety guard process, in particular, comparing the absolute value of the difference between the numerical value of the safeguard data and the numerical value of the threshold data, with a stability tolerance value, comprises:

- comparing the absolute value of the difference between the numerical value of the safeguard data and a numerical value of the control threshold SP2 with said stability tolerance value.

[0051] In one embodiment, the safety guard process, in particular, comparing the absolute value of the difference between the numerical value of the safeguard data and the numerical value of the threshold data, with a stability tolerance value, comprises:

- comparing the absolute value of the difference between the numerical value of the safeguard data and a numerical value of the safety threshold SP1 with a safety tolerance value being within said stability tolerance value.

[0052] According to one embodiment, the safety guard process comprises carrying said security action when the absolute value is above the stability tolerance value, in particular carrying out the control system action when the absolute value is above the stability tolerance value. In one embodiment, the safety guard process comprises carrying out the safety system action when the absolute value is above the safety tolerance value.

[0053] The term "safety tolerance value" refers to a security margin that the absolute value of the difference between the numerical value of safeguard data and the numerical value of the control threshold data should not exceed at the risk of triggering the safety system action.

[0054] The term "stability tolerance value" refers to a security margin that the absolute value of the difference between the numerical value of safeguard data and the numerical value of the control threshold data should not exceed at the risk of triggering the security action, in particular the control system action.

[0055] According to one embodiment, the threshold data remains constant during at least a functional phase during which an action modifying the fuel flow rate and/or the stabilizing fuel flow rate is operated.

[0056] Alternatively, the threshold data are continuously updated based on the flow data during at least said functional phase. For example, during a start-up functional phase, during which a plant configured to carry out the combustion process is being started up, there is a capacity increase in terms of the flow rates, such that the threshold data are adapted to meet this capacity increase.

[0057] Parameters that can change the load of the plant during the start-up phase are for example:

- combustion air temperature;
- flue gas recycling;
- flue gas temperature; and/or
- excess combustion air.

[0058] According to one embodiment, the threshold data remain constant during each of said functional phase.

[0059] Alternatively, the threshold data may vary be-

tween each of said functional phase.

[0060] According to one embodiment, the stabilizing fuel may comprise:

- a hydrogen gas fuel;
- a methane or higher hydrocarbons fuel;
- a carbon monoxide fuel;
- a methanol fuel
- or a combination of two or more of these fuels.

[0061] By "stabilizing fuel" is meant a fuel having a composition such that the combustion of the fuel can be stabilized while being combusted with said stabilizing fuel.

[0062] According to one embodiment, the combustion process comprises:

- providing the fuel flow rate and the stabilizing fuel rate to a burner and
- combusting the fuel with the stabilizing fuel in said burner with the help of an oxidant, such as oxygen enriched air. Oxygen enriched air has a further stabilizing effect for the combustion process.

[0063] According to one embodiment, the burner is part of a furnace, in particular an industrial furnace.

[0064] The invention also relates to an apparatus comprising:

- a fuel stream line, in particular an ammonia fuel stream line, configured to be connected to at least a burner to provide a fuel to said burner, optionally via a fuel header;
- a stabilizing fuel stream line, configured to be connected to the same burner to provide a stabilizing fuel to said burner, optionally via the fuel header ;
- at least one flow meter configured to measure a flow rate of the fuel in the fuel stream line;
- at least one flow meter configured to measure a flow rate of the stabilizing fuel in the stabilizing fuel stream line;
- a logic controller connected to the flow meters and configured to perform a safety guard process of the invention as described above.

[0065] In one embodiment, the apparatus comprises at least two fuel headers, respectively configured to provide the fuel to said burner and the stabilizing fuel to said burner.

[0066] A "logic controller" refers to any type of generic control device such as programmable logic controller, a processor unit or a microprocessor.

[0067] The invention may comprise at least one of the following features, taken independently or in combina-

tion.

[0068] The invention also relates to an installation comprising:

- an apparatus as described above; and
- at least one burner configured to perform a combustion of the fuel with the stabilizing fuel in said burner, wherein the fuel stream line and the stabilizing fuel stream line are connected to the burner, so as to perform said combustion.

[0069] According to one embodiment, the fuel stream line and the stabilizing fuel stream line are connected to each other such that the fuel and stabilizing fuel can be mixed.

[0070] Said flow meters are capable of continuously measuring the fuel flow rate and/or the stabilizing fuel flow rate even if one of these flow meters of each fuel stream line is out of order.

[0071] The invention also relates to the use of the safety guard process as previously described in the field of electrical power generation, for example in a turbine, in particular in a gas turbine.

[0072] In one embodiment, the invention relates to the use of the safety guard process in the field of a fired industrial process, for example in the fields of metallurgy, glasswork (glass plants), oil refining and chemical processing.

[0073] In one embodiment, the invention relates to the use of the safety guard process in any type of fields in which the fuel is combusted to provide heat to an endothermic reaction, such as ammonia cracking (ammonia splitting reaction), hydrocarbon reforming reaction, steam cracking, steam methane reforming.

[0074] Note that all of the features and configurations described above are purely examples. Other features, details and advantages of the invention will become clearer on reading the detailed description set out below, together with several embodiments provided purely as examples and by way of indication, with reference to the attached schematic drawing, in which:

Fig. 1 schematically shows a safety guard process of the invention, as an illustrative and non-limiting example.

Fig. 2 schematically shows a safety guard process of the invention, as another illustrative and non-limiting example.

Fig. 3 schematically shows a safety guard process of the invention.

Fig. 4 schematically shows a control system action of the safety guard process of the invention as an illustrative and non-limiting example.

Fig. 5 schematically shows a safety system action of the safety guard process of the invention as an illustrative and non-limiting example.

Fig. 6 schematically shows an installation of the invention as an illustrative and non-limiting example.

[0075] Referring to figures 1 to 3, an example to a safety guard process 2 for a combustion process comprising the combustion of an ammonia fuel 4, with a stabilizing fuel 6, is represented.

[0076] By "stabilizing fuel" 6 is meant a fuel having a composition such that the combustion of the fuel can be stabilized while being combusted with said stabilizing fuel.

[0077] The stabilizing fuel 6 may comprise:

- a hydrogen gas fuel;
- a methane or higher hydrocarbons fuel;
- a carbon monoxide fuel;
- a methanol fuel;
- or a combination of two or more of these fuels.

[0078] As particularly illustrated in figure 3, said safety guard process 2 comprises the following steps of:

- providing flow rate data of the fuel 4, and flow rate data of the stabilizing fuel 6 (S10);
- determining safeguard data 8 based on said flow rate data of the fuel 4 and of the stabilizing fuel 6 (S20);
- providing threshold data SP indicating a stability limit of the safeguard data 8 (S30; S32; S34);
- comparing the safeguard data 8 with the threshold data SP (S40; S42; S44); and
- carrying out a security action 12 (S50), based on the result of said comparison of the safeguard data 8 with the threshold data SP.

[0079] The flow rate data of the fuel 4 is related to a flow rate of the fuel 4 (or fuel flow rate) and the flow rate data of the stabilizing fuel 6 is related to a flow rate of the stabilizing fuel 6 (or stabilizing fuel flow rate). The flow rate data of the fuel 4 can be for example a heating value of the fuel flow rate sent to a burner 104 and the flow rate data of the stabilizing fuel 6 can be for example a heating value of the stabilizing fuel flow rate sent to said burner.

[0080] Thanks to the invention, a security action 12 to control the combustion process of the fuel 4 and the stabilizing fuel 6, is carried out, based on the flow rate of said fuels 4, 6.

[0081] This circumvents the dependence on parameters, for example the temperature of the flame resulting from the combustion of said fuels 4, 6, which may deviate or may introduce bias into the flame detection.

Thus, this avoids delaying or anticipating the ideal moment at which the security action should be carried out.

[0082] Put differently, thanks to the invention, the ideal moment at which the security action 12 should be carried out, is precisely determined without needing to change setting parameters of the flame detection, or to change a flame detecting device (not depicted) itself, each time the combustion of said fuels 4, 6 influences the flame detection. Therefore, the flame detection and the security action to be carried out are simple, fast and cost-effective compared with a classical flame detection using the flame detection device.

[0083] The safeguard data 8 are determined based on a ratio of an ammonia fuel flow rate, NH₃, to the stabilizing fuel flow rate SF. The ratio is multiplied by a constant k. The ratio of the safeguard data is obtained by a measurement of the fuel flow rate NH₃ and/or a measurement of the stabilizing fuel flow rate SF.

[0084] Now referring to figures 1 and 2, the security action 12 comprises:

- a control system action 20 comprising changing a parameter of the combustion process to bring back the safeguard data 8 within its stability limit; and
- a safety system action 30 comprising stopping the combustion process.

[0085] The control system action 20 and the safety system action 30 are performed independently and simultaneously. The control system action 20 is carried out before the safety system action 30.

[0086] As shown in figure 2, the safety guard process 2 comprises setting a stabilization deadline 40 before performing the following steps of the safety guard process 2:

- providing a new flow rate data of an ammonia fuel 4, and a new flow rate data 8 of the stabilization fuel 6 and determining a new safeguard data 8 based on said new flow rate data of the fuel 4 and of the stabilizing fuel 6; and
- comparing new safeguard data 8 with the threshold data SP.

[0087] This way, waiting the stabilization deadline 40 allows a time lapse between a temporary anomaly of the flow rate data of said fuels 4, 6, and the control system action 20 so as to let the flow rate data of said fuels 4, 6 to be stabilized by its own.

[0088] Now referring to figure 4, an example of control system action 20 is represented.

[0089] In particular, the threshold data SP comprises a control threshold SP2, and the control system action 20 is carried out based on the result of the comparison of the

safeguard data with the control threshold SP2.

[0090] In other words, the safety guard process 2 comprises comparing the safeguard data 8 with the control threshold SP2, as long as the safeguard data 8 are within the stability limit of said threshold data.

[0091] The control system action 20, changing a parameter of the combustion process, comprises adjusting the fuel flow rate and/or the stabilizing fuel flow rate such that the safeguard data 8 are brought back within its control stability limit. (S50)

[0092] In one embodiment, the control system action 20, adjusting the fuel flow and/or the stabilizing fuel flow rate, comprises keeping constant the fuel flow rate NH3 while increasing the stabilizing fuel flow rate SF (S50).

[0093] Alternatively, the control system action 20 comprises keeping constant the fuel flow rate NH3 while increasing the stabilizing fuel flow rate SF (S50).

[0094] Alternatively, the control system action 20 comprises decreasing the fuel flow rate NH3 while increasing the stabilizing fuel flow rate SF (S50).

[0095] Thus, the safeguard data 8 can be adjusted with a steeper variation.

[0096] The control system action 20 comprises comparing the safeguard data 8 with the control threshold data SP2 as long as the safeguard data 8 are within the stability limit of said threshold data SP2 (S70).

[0097] The control system action 20 comprises directing to a safety system action 30 when the safety guard data 8 are outside of the stability limit of said threshold data SP2 (S80).

[0098] Now referring to figure 5, an example of safety system action 30 is represented.

[0099] The threshold data SP further comprises a safety threshold SP1 indicating a safety limit of the safeguard data, the stability limit being within said stability limit and the safety system action 30 is performed based on the result of said comparison of the safeguard data 8 with the safety threshold SP1.

[0100] The safety limit comprises a range of the safeguard data for which the combustion process is running in accordance to safe combustion criteria.

[0101] Therefore, when the status of the combustion of said fuels 4, 6 is likely to compromise the safety of the combustion in view of the safeguard data 8, i.e., the safe combustion criteria is not met, the combustion process is stopped or a plant in which the combustion process is being carried out is shut down.

[0102] For example, this may be a situation in which the ammonia fuel is in a large excess compared with a stabilizing fuel, for example hydrogen gas, such that the combustion of the ammonia fuel leads to safety issues.

[0103] The threshold data SP, SP1, SP2 remains constant during at least a functional phase during which an action is operated on the fuel flow rate NH3 and/or the stabilizing fuel flow rate SF is operated.

[0104] Alternatively, the threshold data SP, SP1, SP2 are continuously updated based on the flow data during

at least said functional phase. For example, during a start-up functional phase, during which a plant configured to carry out the combustion is being started up there is a capacity increase in terms of the flow rates NH3, SF, such that the threshold data SP, SP1, SP2 are adapted to meet this capacity increase.

[0105] The parameters that can change the load of the plant during the start-up phase are for example:

- 10 - combustion air temperature;
- flue gas recycling;
- flue gas temperature; and/or
- 15 - excess combustion air.

[0106] Now referring to figure 6, an example of an installation 100 of the invention is represented.

20 [0107] Said installation 100 comprises:

- an apparatus 102 comprising:

- 25 ○ an ammonia fuel stream line 106, configured to be connected to four burners 104 to provide a fuel 4 to said burners 104 via a fuel header 120;
- a stabilizing fuel stream line 108, configured to be connected to the same burners to provide a stabilizing fuel 6 to said burners via the fuel header 120;
- 30 ○ two flow meters 130 configured to measure a flow rate of the fuel NH3 in the fuel stream line 106;
- two flow meters 130 configured to measure a flow rate of the stabilizing fuel SF in the stabilizing fuel stream line 108;
- 35 ○ a logic controller 140 connected to the flow meters (see lightning symbol in figure 6) and configured to perform a safety guard process 2.

[0108] Said installation 100 further comprises:

- four burners 104 configured to be connected to the apparatus 102.

45 [0109] The four burners 104 are configured to perform a combustion of the fuel 4 with the stabilizing fuel 6 in said burners, wherein the fuel stream line 106 and the stabilizing fuel stream line 108 are connected to the fuel header 120 of the burners 104 so as to perform said combustion.

[0110] The connection 142 between the logic controller 140 and the flow meters 130 can be wired or wireless.

50 [0111] A "logic controller" 140 refers to any type of generic control device such as programmable logic controller, a processor unit or a microprocessor.

[0112] The fuel flow NH3 and the stabilizing fuel flow SF are mixed in the fuel header 120 so as to be distributed

into four burners 104. The fuel stream line 106 and the stabilizing fuel stream line 108 are connected to each other such that the fuel 4 and stabilizing fuel 6 can be mixed.

[0113] Said flow meters 130 are capable of continuously measuring the fuel flow rate NH₃ and/or the stabilizing fuel flow rate SF even if one of these flow meters of each fuel stream line 106, 108 is out of order.

Claims

1. Safety guard process (2) for a combustion process comprising the combustion of a fuel (4), in particular an ammonia fuel (4), with a stabilizing fuel (6), said safety guard process (2) comprises the following steps of:

- providing flow rate data of the fuel (4), and flow rate data of the stabilizing fuel (6) (S10);
- determining safeguard data (8) based on said flow rate data of the fuel (4) and of the stabilizing fuel (6) (S20);
- providing threshold data (SP, SP2) indicating a stability limit of the safeguard data (8) (S30);
- comparing the safeguard data (8) with the threshold data (SP, SP2) (S40); and
- carrying out a security action (12), based on the result of said comparison of the safeguard data (8) with the threshold data (S50).

2. Safety guard process (2) according to claim 1, wherein the security action (12) comprises triggering a visual alarm or a sound alarm.

3. Safety guard process (2) according to claim 1 or 2, wherein the security action (12) comprises:

- at least a control system action (20) comprising changing a parameter of the combustion process to bring back the safeguard data (8) within its stability limit.

4. Safety guard process (2) according to the preceding claim, wherein the control system action (20), in particular, changing a parameter of the combustion process, comprises adjusting the fuel flow rate and/or the stabilizing fuel flow rate such that the safeguard data (8) are brought back within its control stability limit.

5. Safety guard process (2) according to any one of claims 3 or 4, wherein the threshold data (SP) comprises a control threshold (SP2), and the control system action (20) is carried out based on the result of the comparison of the safeguard data (8) with the control threshold (SP2).

6. Safety guard process (2) according to any one of the preceding claims, wherein the security action (12) comprises:

- a safety system action (30) comprising stopping the combustion process.

7. Safety guard process (2) according to the preceding claim, wherein the threshold data (SP) further comprises a safety threshold (SP1) indicating a safety limit of the safeguard data (8), the stability limit being within said safety limit and the safety system action (30) is performed based on the result of said comparison of the safeguard data (8) with the safety threshold (SP1).

8. Safety guard process (2) according to any one of claims 6 or 7 in combination with one of claims 3 to 5, comprising:

- setting a control deadline during which the control system action (20) is performed and if the safeguard data (8) is determined to be still outside of the stability limit of the safeguard data (8) after said control deadline based on the result of the comparison (S60) between the safeguard data (8) with the control threshold (SP2), the process comprises performing the safety system action (30).

9. Safety guard process (2) according to any one of the preceding claims, wherein the security action (12) comprises setting a stabilization deadline (40) before performing the following steps:

- providing a new flow rate data of the fuel (4), in particular of an ammonia fuel (4), and a new flow rate data of the stabilization fuel (6) and determining a new safeguard data based on said new flow rate data of the fuel (4) and of the stabilizing fuel (6);
- comparing the new safeguard data (8) with the threshold data (SP, SP2).

10. Safety guard process (2) according to any one of the preceding claims, wherein the safeguard data (8) are determined based on a ratio between the fuel flow rate and the stabilizing fuel flow rate.

11. Safety guard process (2) according to any one of the preceding claims, in particular, comparing the safeguard data (8) with the threshold data (SP, SP1, SP2), comprising:

- comparing the absolute value of a difference between a numerical value of the safeguard data (8) and a numerical value of the threshold data (SP, SP1, SP2), with a stability tolerance value.

12. Safety guard process (2) according to any one of the preceding claims, wherein the stabilizing fuel (6) comprises:

- a hydrogen gas fuel; 5
- a methane or higher hydrocarbons fuel;
- a carbon monoxide fuel;
- a methanol fuel
- or a combination of two or more of these fuels. 10

13. Safety guard process (2) according to any one of the preceding claims, wherein the combustion process comprises:

- providing the fuel flow rate and the stabilizing fuel rate to a burner (104) and 15
- combusting the fuel (4) with the stabilizing fuel (6) in said burner (104) with the help of an oxidant, such as oxygen enriched air. 20

14. Apparatus (102) comprising:

- a fuel stream line (106), in particular an ammonia fuel stream line (106), configured to be connected to at least a burner (104) to provide a fuel (4) to said burner (104), optionally via a fuel header (120); 25
- a stabilizing fuel stream line (108), configured to be connected to the same burner (104) to provide a stabilizing fuel (6) to said burner (104), optionally via the fuel header (120); 30
- at least one flow meter (130) configured to measure a flow rate of the fuel (4) in the fuel stream line (106);
- at least one flow meter (130) configured to measure a flow rate of the stabilizing fuel (6) in the stabilizing fuel stream line (108); 35
- a logic controller (140) connected to the flow meters (130) and configured to perform a safety guard process (2) according any one of the preceding claims. 40

15. Use of the safety guard process (2) according to claims 1 to 13, in the field of a fired industrial process, for example in the fields of metallurgy, glasswork, oil refining and chemical processing; and/or in any type of fields in which the fuel is combusted to provide heat to an endothermic reaction, such as ammonia cracking, hydrocarbon reforming reaction, steam cracking, steam methane reforming. 45 50

55

Fig. 1

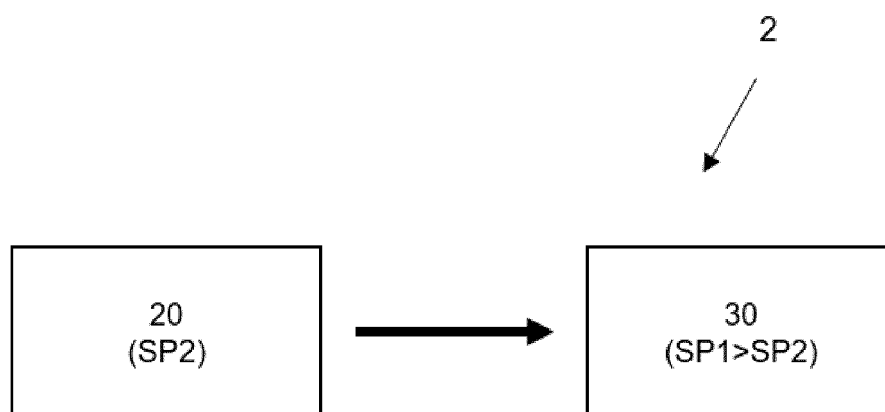


Fig. 2

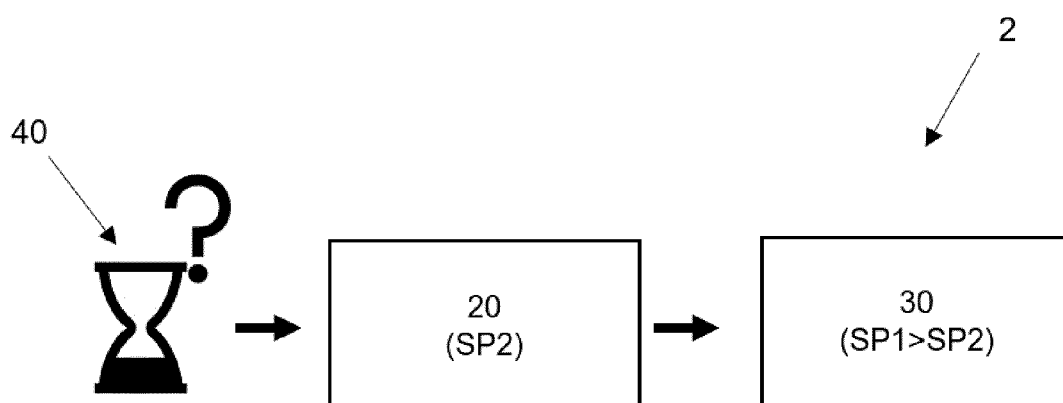


Fig. 3

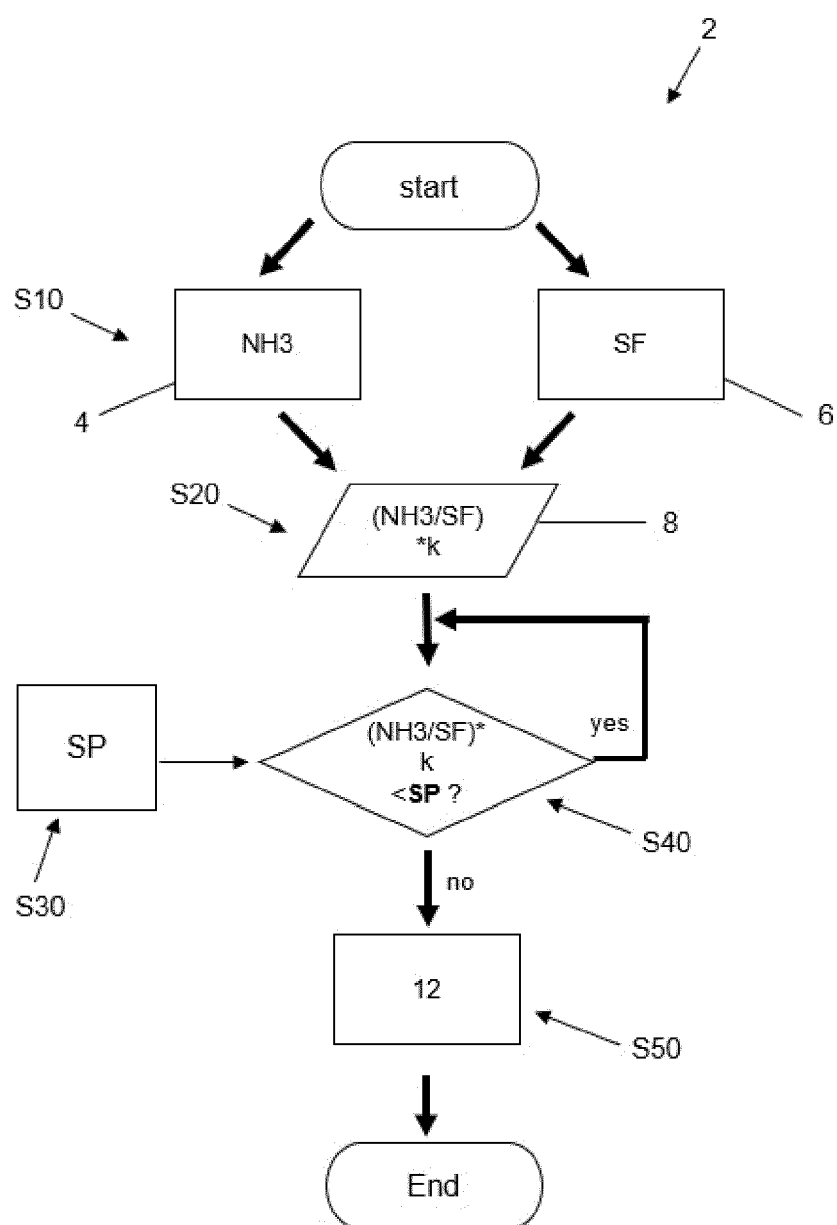


Fig. 4

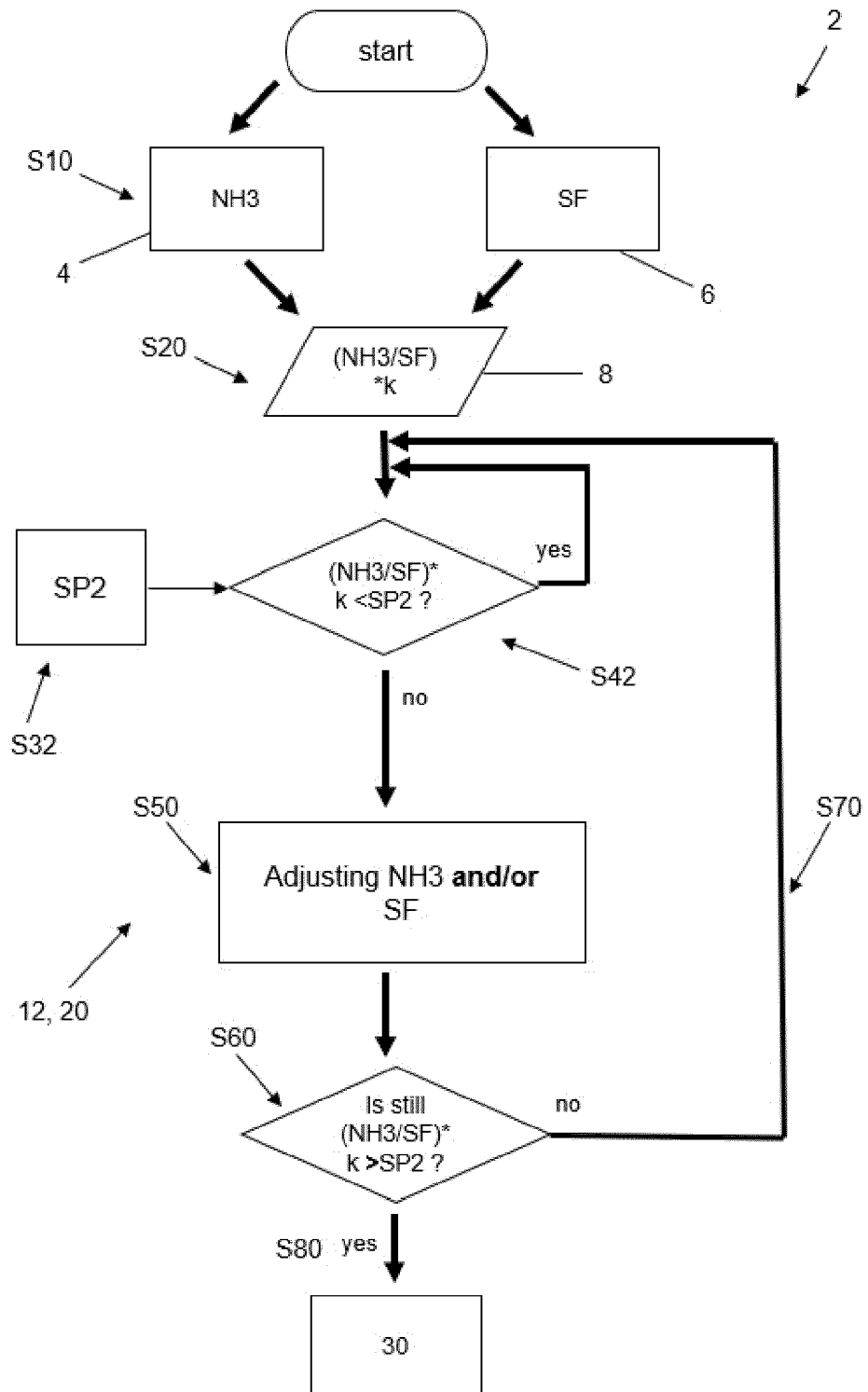


Fig. 5

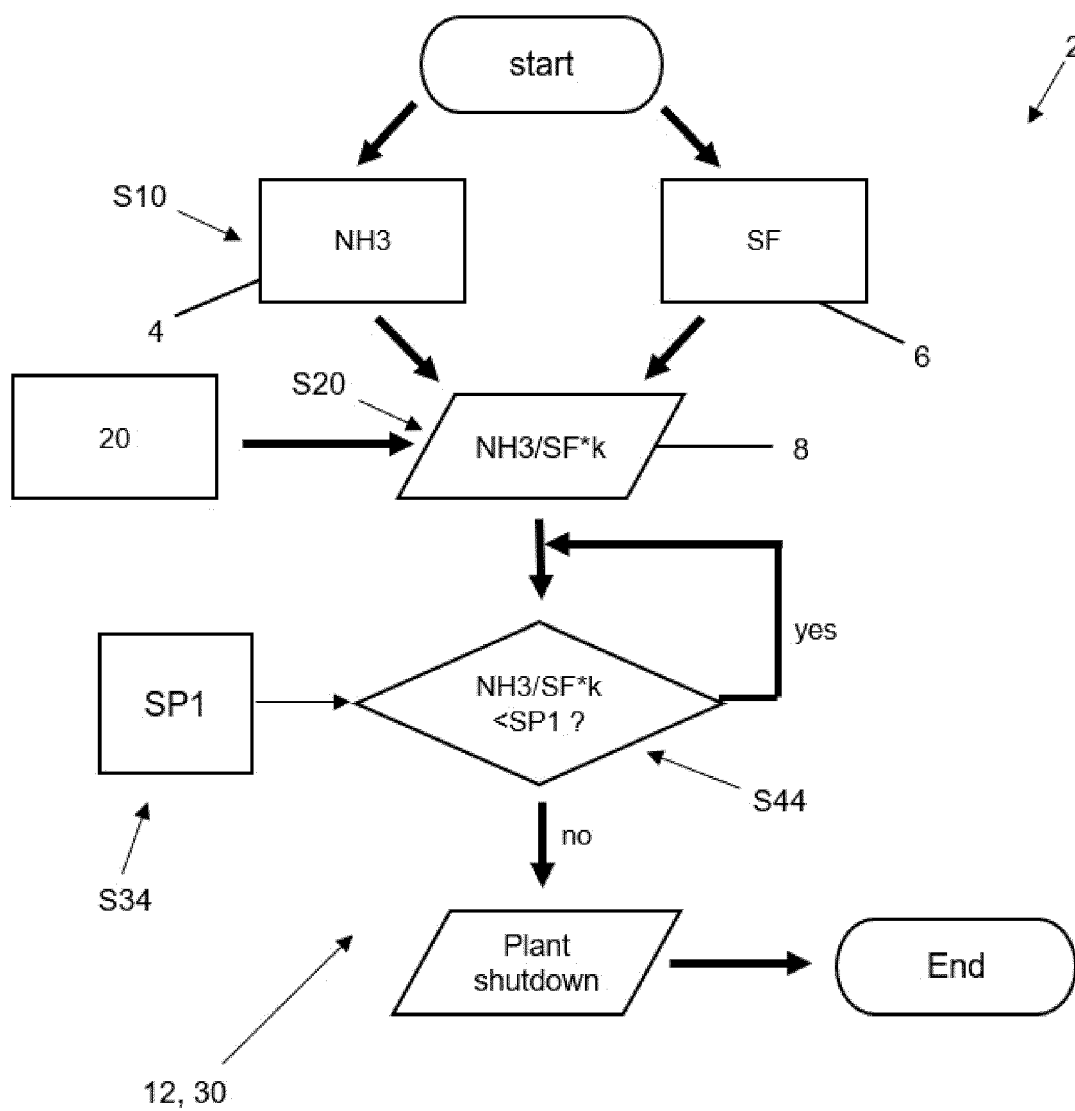
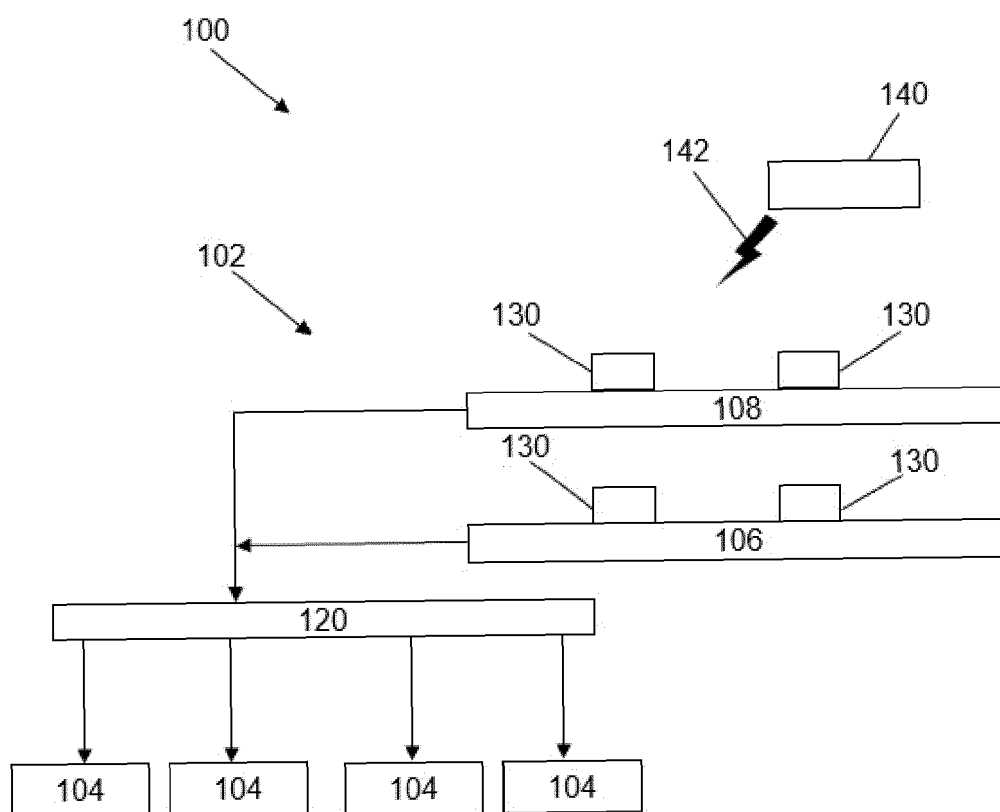


Fig. 6





EUROPEAN SEARCH REPORT

Application Number

EP 24 15 1154

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	JP 5 159741 B2 (HITACHI LTD) 13 March 2013 (2013-03-13) * paragraphs [0017], [0067], [0114] - [0116], [0121] - [0128], [0142], [0143] * * figures 9, 10 *	1-15	INV. F23N1/00 F23N5/18 F23N5/24
X	JP H05 257544 A (N.N.) 8 October 1993 (1993-10-08) * paragraph [0012] * * claim 1; figure 2 *	1-4, 6, 7, 10-15	
X	EP 3 467 385 B1 (GEN ELECTRIC [US]) 8 June 2022 (2022-06-08) * paragraphs [0054], [0055], [0076] * * figures 7A, 7B *	1-7, 9-15	
			TECHNICAL FIELDS SEARCHED (IPC)
			F23N
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		24 June 2024	Vogl, Paul
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 & : 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 15 1154

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-06-2024

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 5159741 B2	13-03-2013	JP 5159741 B2	13-03-2013
		JP 2011074844 A	14-04-2011

JP H05257544 A	08-10-1993	NONE	

EP 3467385 B1	08-06-2022	CA 3018110 A1	03-04-2019
		CN 109595080 A	09-04-2019
		EP 3467385 A1	10-04-2019
		JP 2019090405 A	13-06-2019
		US 2019101062 A1	04-04-2019

15

20

25

30

35

40

45

50

55

EPO FORM P0459

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