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(54) **CONTROL METHOD FOR A GAS BOILER**

(57) Method (100) for controlling the operation of a combustion appliance (1), in particular a gas boiler, wherein the combustion appliance (1) is operable between a minimum load (Q_{min}) and a maximum load (Q_{max}), the method comprising providing (S101) a mixture of air and fuel gas to the combustion appliance (1), controlling (S102) one or more actuators (2, 3) of the combustion appliance (1) to regulate the air flow and/or the fuel gas flow, and defining (S103) a lambda value, the lambda value being an air to fuel gas ratio of the mixture, wherein in a load range between the minimum load (Q_{min}) and the maximum load (Q_{max}), the lambda value first decreases and then stops to decrease.

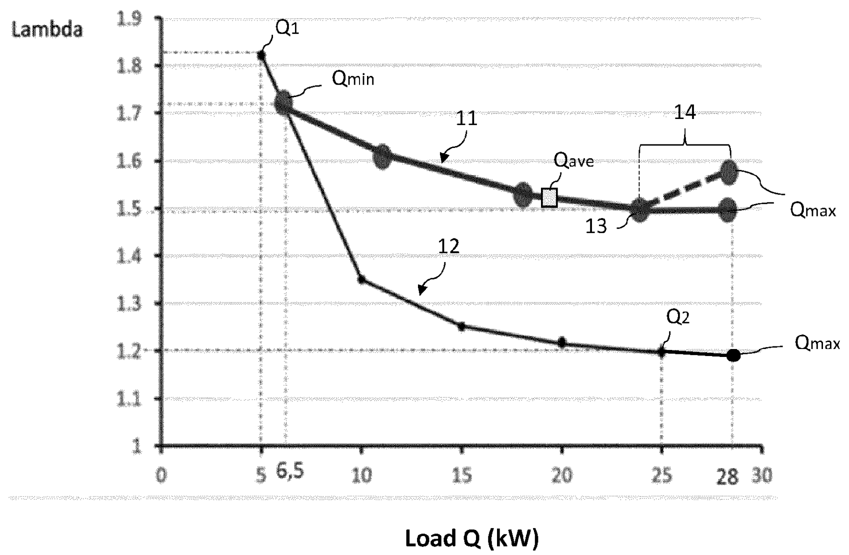

FIG. 3

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Description

[0001] The invention relates to a method for controlling the operation of a combustion appliance, in particular a gas boiler. Also, the invention relates to a computer program product executed by a computer or control unit carrying out the above method, a data processing apparatus comprising a processor for executing said computer program product, and a computer readable data carrier having stored thereon the computer program product. In addition, the invention relates to a combustion appliance comprising means for carrying out the method.

[0002] Gas boilers combust gas fuel to heat water for domestic use and/or central heating system facilities in buildings. The boilers can be used to operate in different modes, such as continuous-flow heaters, for preparing hot water, etc. In gas boilers, the power output is substantially determined by the setting of the supply of fuel gas and air and by the mixture ratio between gas and air that is set. The temperature produced by the flame is also, among other things, a function of the mix ratio between fuel gas and air. An important factor influencing the safety of the boiler is the flame or burner stability, which is defined in terms of a stable combustion and thus no or next to no occurrence of flashbacks.

[0003] The flame speed is an important factor on the flame stability and a high flame speed can cause a flashback. In case the flame speed becomes greater than the mixture velocity, the flame can traverse in the upstream direction, which is toward the burner deck and even across the burner deck into the burner causing a so-called flashback. Flashback can be triggered e.g. by a change in a ratio of the air to the fuel gas in the mixture, by a change in composition of the fuel gas. When the mixture velocity becomes too high and rises above a so-called blow-off speed, blow-off may occur which means that the flame is blown-off the burner deck, with the consequence that the flame extinguishes or suffers incomplete combustion. For this reasons, the mixture velocity and/or the flame speed needs to be controlled. The flame speed is a function of the ratio of air to fuel gas in the mixture (in the following this ratio can also be indicated as lambda). Around lambda 1 the flame speed is the highest and if lambda increases the flame speed decreases.

[0004] The control of mixture velocity is much more important when the boiler uses hydrogen as fuel gas rather than other fuel gasses such as methane. In fact, flashback can occur more easily in hydrogen boilers since the laminar flame speed of hydrogen air mixture is around eight times higher than the flame speed for methane air mixture (with reference to the stoichiometric condition).

[0005] Methods are known in prior art for controlling the value of lambda during the operation of a combustion appliance. In operation between a minimum load and a maximum load for example, the value of lambda can be controlled to continuously lower its value. Usually, the ratio between the lambda value at the minimum load and the lambda value at the maximum load is higher than 1.2, wherein the value at the maximum load is less than 1.3. However, this could lead to a higher risk of flashback, a higher emissions in the flue and higher presence of nitrogen oxides (NOx).

[0006] It is therefore desirable to provide a method for controlling the operation of a gas boiler that allows a bigger margin of operation of the combustion appliance as well as a mitigation of the risk of flashback, emissions in the flue and NOx without strongly affecting the efficiency of the combustion appliance.

[0007] The object is solved by a method for the operation of a combustion appliance, in particular a gas boiler, wherein the combustion appliance is operable between a minimum load and a maximum load, the method comprising:

providing a mixture of air and fuel gas to the combustion appliance,
controlling one or more actuators of the combustion appliance to regulate the air flow and/or the fuel gas flow, and
defining a lambda value, the lambda value being an air to fuel gas ratio of the mixture, wherein in a load range between the minimum load and the maximum load, the lambda value first decreases and then stops to decrease.

[0008] Advantageously, the value of the air to the fuel gas ratio in the gas mixture is controlled to avoid the risk of flashback and at the same time. to reduce the emissions in the flue and the presence of NOx.

[0009] In one example, in a load range between the minimum load and the maximum load, the lambda value first decreases and then increases or the lambda value first decreases and then is constant. Thus, stopping the decrease of lambda value can occur by increasing the lambda value or by keeping the lambda value constant. In particular, the lambda value is not continuously lowered when passing from the minimum load to the maximum load but there is a range wherein said value increases or remains constant. It is noted that this trend goes beyond the normal fluctuations of the measured value of lambda. As a matter of fact, the load range between the minimum load and the maximum load comprises a first load range (comprising the minimum load), wherein the lambda value continuously decreases, and a second load range (consecutive the first load range and comprising the maximum load), wherein the lambda value does not decrease any more, i.e., continuously increases or is constant.

[0010] In another example, the lambda value stops to decrease when the load has reached at least 80% of the maximum load, in particular 90% of the maximum load. In particular, the lambda value stops to decrease at a reference load value, wherein in a load range between the reference load value and the maximum load, the lambda value increases, in particular continuously increases or the lambda value is constant. In particular, the reference load value is a load value close to the maximum load. In other words, the behaviour of stopping decreasing the lambda value occurs when the combustion appliance is almost operating at the maximum load.

[0011] According to an example, in the load range between the minimum load and the maximum load, the ratio between the lambda value at the minimum load and the lambda value at the maximum load is lower than 1.20, in particular 1.13. In this way, there is a limited variation of the lambda value when the combustion appliance is operating at the minimum load and at a maximum load.

[0012] In one example, the lambda value is higher than 1.3, in particular higher than1.5, when the combustion appliance is operated at the maximum load. For example, the lambda value can be 1.6 when the combustion appliance is operated at the maximum load.

[0013] Also, the lambda value is higher than 1.7, in particular 1.8, when the combustion appliance is operated at the minimum load. For example, the lambda value can be 1.92 when the combustion appliance is operated at the minimum load.

[0014] According to an example, in the load range between an average load and the maximum load, the lambda value is, in particular continuously, lowered, in particular by less than 2%, and then is increased or is constant, the average load being the average value of the lambda in the load range between the minimum load and the maximum load. Specifically, the average load is defined as the difference between the maximum load value and the minimum load value divided by 2 and added to the minimum load value. In particular, the lambda value at the average load is higher than 1.5, in particular is comprised between 1.51 and 1.56. In other words, once the combustion appliance is operating at the average load, the lambda value has almost reached the minimum value.

[0015] In a further example, the maximum load is comprised between 27kW and 29 kW, in particular 28kW and the minimum load is comprised between 6kW and 7kW, in particular 6.5kW.

[0016] According to one aspect of the invention, a computer program product is provided. This product comprises instructions which, when the program is executed by a computer or control unit, cause the computer or the control unit to carry out the inventive method.

[0017] In a further aspect of the invention, a data processing apparatus is provided. This data processing apparatus comprises a processor for executing the inventive computer program product. Also, a computer readable data carrier is provided, the carrier having stored thereon the inventive computer program product.

[0018] According to one aspect of the invention, a combustion appliance, in particular a gas boiler, is provided, the combustion appliance comprising means for carrying out the inventive method Examples of combustion appliances can include furnaces, water heaters, boilers, direct/in-direct make-up air heaters, power/jet burners and any other residential, commercial or industrial combustion appliance.

[0019] In particular, the appliance including the present system can be a gas boiler for the combustion of hydrogen gas. In this case, it is intended a fuel gas that comprises at least 20% hydrogen or pure hydrogen.

[0020] In one example, the combustion appliance comprises a burner, wherein the ratio between the perforated surface area of the burner and the total surface area of the burner is comprised between 15% and 20%, in particular 18.7%.

[0021] It is noted that the particular configuration of the burner in terms of perforated surface area as well as of the manifold mixer in terms of cross section area can reduce the pressure loss of the combustion appliance. The reduction of pressure loss can affect the setting parameters to achieve a bigger margin of operation.

[0022] In the figures, the subject-matter of the invention is schematically shown, wherein identical or similarly acting elements are usually provided with the same reference signs.

Figure 1 shows a schematic representation of a combustion appliance according to an example.

Figure 2 shows a flow chart of a method for controlling the operation of a combustion appliance according to an example.

Figure 3 show the variation of the lambda value as a function of the load according to an example.

[0023] Figure 1 illustrates a heating system 15 comprising a combustion appliance 1 such as gas boiler used for the combustion of fuel gas, for example containing hydrocarbons and/or hydrogen. The fuel gas is mixed with air and is provided to the burner 5 through a gas mixture channel 8, the burner 5 being coupled to a heat exchanger 7 for heating water for domestic use and/or central heating system facilities in buildings. The gas mixture channel 8 receives air from an air supply line 9 and fuel gas from a gas supply line 10. The flow of air - and correspondingly the flow of the air/fuel gas mixture - can be regulated by a fan element 2 located in the air supply line 9. Advantageously, the fan element 2 is located upstream the region where the fuel gas is inserted into the gas mixture channel 8. The gas supply line 10 is provided with a gas valve 3 for regulating the fuel gas flow entering the gas mixture channel 8. The heating system 15 comprises furthermore a control unit 4 connected to the fan element 2 and the gas valve 3 to regulate and eventually adapt the air to fuel gas ratio. A manifold mixer 6 is provided in gas mixture channel 8 at the joint region where the gas supply line 10 is connected to the gas mixture channel 8.

[0024] By acting on the fan element 2 and/or the gas valve 3, the control unit 4 can regulate the air to fuel gas ratio in the gas mixture channel 8 that is supplied to the burner 5. Accordingly, the value of lambda can be varied during the operation of the combustion appliance. For example, if the combustion appliance 1 is operating between a minimum load to a maximum load, the value of lambda can be changed in the load range between the minimum load and the maximum load.

[0025] Figure 2 shows a flow chart of the method 100 for controlling the operation of the combustion appliance 1 and in particular for operating a gas boiler, as described above, when operating between the minimum load and the maximum load.

[0026] At step S101, the method comprises providing a mixture of air and fuel gas to the combustion appliance 1 and at step S102 the method comprises controlling one or more actuators to regulate the air flow and/or the fuel gas flow. The actuators can be for example the fan element 2 to regulate the air flow and the gas valve 3 to regulate the fuel gas flow. At step S103, the air to fuel gas ratio of the mixture is defined. This ratio is the lambda value. In the load range between the minimum load and the maximum load, the lambda value first decreases and then stops to decrease. A decrease interruption is intended here that the lambda value can increase or can remain constant.

[0027] The trend of the lambda value in the load range is shown in figure 3. In particular, the figure illustrates a comparison between a first lambda value curve 11 according to the present disclosure (thicker line) and a second lambda value curve 12 according to prior art (thinner line) describing the variation of the lambda value as a function of the operating load of the combustion appliance 1.

[0028] According to the second lambda value curve 12, or prior art lambda value, the value of lambda continuously decreases within a load range defined by a first load value (Q_1) representing the lowest load value (for example 5kW) and a second load value (Q_2) representing the highest load value (for example 25kW). Usually, at the first load value (Q_1) lambda has the highest value (for example more than 1.8) and at the second load value (Q_2) lambda assumes the smallest value (for example less than 1.3, in particular less than 1.2). It is noted that in the load range between the first and the second load values (Q_1, Q_2), the lambda value curve 12 decreases in a steep way. The ratio between the lambda value at the first load (Q_1) and the lambda value at the second load (Q_2) is more than 1.2, in particular 1.5.

[0029] The first lambda value curve 11 according to the present disclosure behaves in a completely different way. First of all, it is noted that the first lambda value curve 11 is less steep compared to the second lambda value curve 12. As a matter of fact, the ratio between the lambda value at the minimum load (Q_{min}) and the lambda value at the maximum load (Q_{max}) is less than 1.2, in particular 1.13. Furthermore, in the load range between the minimum load (Q_{min}) and the maximum load (Q_{max}) the lambda value decreases, in particular continuously decreases, in a range between the minimum load (Q_{min}) and the reference load 13 (first load range), and then stops to decrease in a final load range 14 between the reference load 13 and the maximum load (Q_{max}) (second load range). In particular, in the final load range 14, the lambda value can either increase (dashed line) or remain constant (straight line). It is furthermore noted that to have more margin (to consider also the tolerances of the system), the maximum load (Q_{max}) is higher than the second load (Q_2) of the second lambda value curve 12. For example, the maximum load (Q_{max}) is at 28kW.

[0030] The first lambda value curve 11 is an example of a possible behavior of the lambda value as a function of the load according to the present disclosure. In this case, the lambda value at the minimum load (Q_{min}) is 1.7 and the lambda value at the maximum load (Q_{max}) is 1.5 or 1.6, so that the ratio between the lambda value at the minimum load (Q_{min}) and the lambda value at the maximum load (Q_{max}) is 1.13 or 1.06. Of course, other specific lambda values can be considered. What is important is that the lambda value curve does not have a steep behavior in the load range between the minimum load (Q_{min}) and the maximum load (Q_{max}). In particular, the ratio between the lambda value at the minimum load (Q_{min}) and the lambda value at the maximum load (Q_{max}) needs to be less than, or equal to, 1.2. For example, the lambda value at the minimum load (Q_{min}) can be 1.8 and the lambda value at the maximum load (Q_{max}) can be 1.5. In another example, the lambda value at the minimum load (Q_{min}) can be 1.92 and the lambda value at the maximum load (Q_{max}) can be 1.6.

[0031] In the load range between the minimum load (Q_{min}) and the maximum load (Q_{max}), an average load (Q_{ave}) can be defined. The average load (Q_{ave}) is the average value of the lambda in the load range between the minimum load (Q_{min}) and the maximum load (Q_{max}). For example, in case the maximum load (Q_{max}) is 28 kW and the minimum load is 6.5 kW, the average load (Q_{ave}) is [(Q_{max}-Q_{min}/2) + Qmin], i.e., [(28 kW-6.5 kW)/2 + 6.5 kW] = 17.25 kW. It is noted that in the load range between the average load (Q_{ave}) and the maximum load (Q_{max}), the lambda value is lowered less than 2% and then is increased or is constant. In particular, the lambda value at the average load (Q_{ave}) is higher than 1.5, in particular is comprised between 1.51 and 1.53, in particular 1.52. Accordingly, the lambda value at the average load (Q_{ave}) is lower than the lambda value at the maximum load (Q_{max}) or is slightly higher than said lambda value at the maximum load (Q_{max}). On the other hand, taking the second lambda value curve 12 into account, the lambda value at the corresponding average load (i.e., 15 kW) is about 1.25 and is lowered more than 2% before reaching the lambda value at the second load (Q_2).

[0032] It is noted that these results can be achieved also due to a combination of parameters affecting the pressure loss of the system.

Reference Signs

[0033]

1	Combustion appliance
2	Fan element
3	Gas valve
4	Control unit
5	Burner
6	Manifold mixer
7	Heat exchanger
8	Gas mixture channel
9	Air supply line
10	Gas supply line
11	First lambda value curve
12	Second lambda value curve (prior art)
13	Reference load value
14	Final load range
15	Heating system
Qmin	Minimum load
Qmax	Maximum load
Q_1	First load
Q_2	Second load
100	Method

Claims

1. Method (100) for controlling the operation of a combustion appliance (1), in particular a gas boiler, wherein the combustion appliance (1) is operable between a minimum load (Q_{min}) and a maximum load (Q_{max}), the method comprising:

providing (S101) a mixture of air and fuel gas to the combustion appliance (1),
controlling (S102) one or more actuators (2, 3) of the combustion appliance (1) to regulate the air flow and/or the fuel gas flow, and
defining (S103) a lambda value, the lambda value being an air to fuel gas ratio of the mixture, wherein in a load range between the minimum load (Q_{min}) and the maximum load (Q_{max}), the lambda value first decreases and then stops to decrease.

2. Method (100) according to claim 1, **characterized in that** in a load range between the minimum load (Q_{min}) and the maximum load (Q_{max}), the lambda value first decreases and then increases or the lambda value first decreases and then is constant.

3. Method (100) according to any one of claims 1 to 2, **characterized in that**:

a. the lambda value stops to decrease when the load has reached at least 80% of the maximum load (Q_{max}), in particular 90% of the maximum load (Q_{max}); and/or
b. the lambda value stops to decrease at a reference load value (13), wherein in a load range between the reference load value (13) and the maximum load (Q_{max}), the lambda value increases, in particular continuously increases or the lambda value is constant.

4. Method (100) according to any one of claims 1 to 3, **characterized in that** the ratio between the lambda value at the minimum load (Q_{min}) and the lambda value at the maximum load (Q_{max}) is lower than 1.20, in particular 1.13.

5. Method (100) according to any one of claims 1 to 4, **characterized in that**:

a. the lambda value is higher than 1.3, in particular higher than1.5, when the combustion appliance (1) is operated at the maximum load (Q_{max}); and/or
b. the lambda value is 1.6 when the combustion appliance (1) is operated at the maximum load (Q_{max}); and/or
c. the lambda value is higher than 1.7, in particular 1.8, when the combustion appliance (1) is operated at the minimum load (Q_{min}); and/or
d. the lambda value is 1.92 when the combustion appliance (1) is operated at the minimum load (Qmin).

6. Method (100) according to any one of claims 1 to 5, **characterized in that**

a. in the load range between an average load (Q_{ave}) and the maximum load (Q_{max}), the lambda value is, in particular continuously, lowered, in particular by less than 2%, and then is increased or is constant, the average load (Q_{ave}) being the average value of the lambda in the load range between the minimum load (Q_{min}) and the maximum load (Q_{max}); and/or
b. the lambda value at the average load (Q_{ave}) is higher than 1.5, in particular is comprised between 1.51 and 1.56.

7. Method (100) according to any one of claims 1 to 6, **characterized in that** the maximum load (Q_{max}) is comprised between 27kW and 29 kW, in particular 28kW and the minimum load (Q_{min}) is comprised between 6kW and 7kW, in particular 6.5kW.

8. Computer program product comprising instructions which, when the program is executed by a computer or control unit, cause the computer or the control unit to carry out the method according to one of the claims 1 to 7.

9. Data processing apparatus comprising a processor for executing the computer program product according to claim 8.

10. Computer readable data carrier having stored thereon the computer program product according to claim 8.

11. Combustion appliance (1), in particular a gas boiler, comprising means for carrying out the method (100) according to any one of claims 1 to 7.

12. Combustion appliance (1) according to claim 11, **characterized in that** the combustion appliance (1) comprises a burner (5), wherein the ratio between the perforated surface area of the burner (5) and the total surface area of the burner (5) is comprised between 15% and 20%, in particular 18.7%.

13. Combustion appliance (1) according to any one of claims claim 11 to 124, **characterized in that** the combustion appliance (1) uses a fuel gas having at least 20% hydrogen or pure hydrogen.

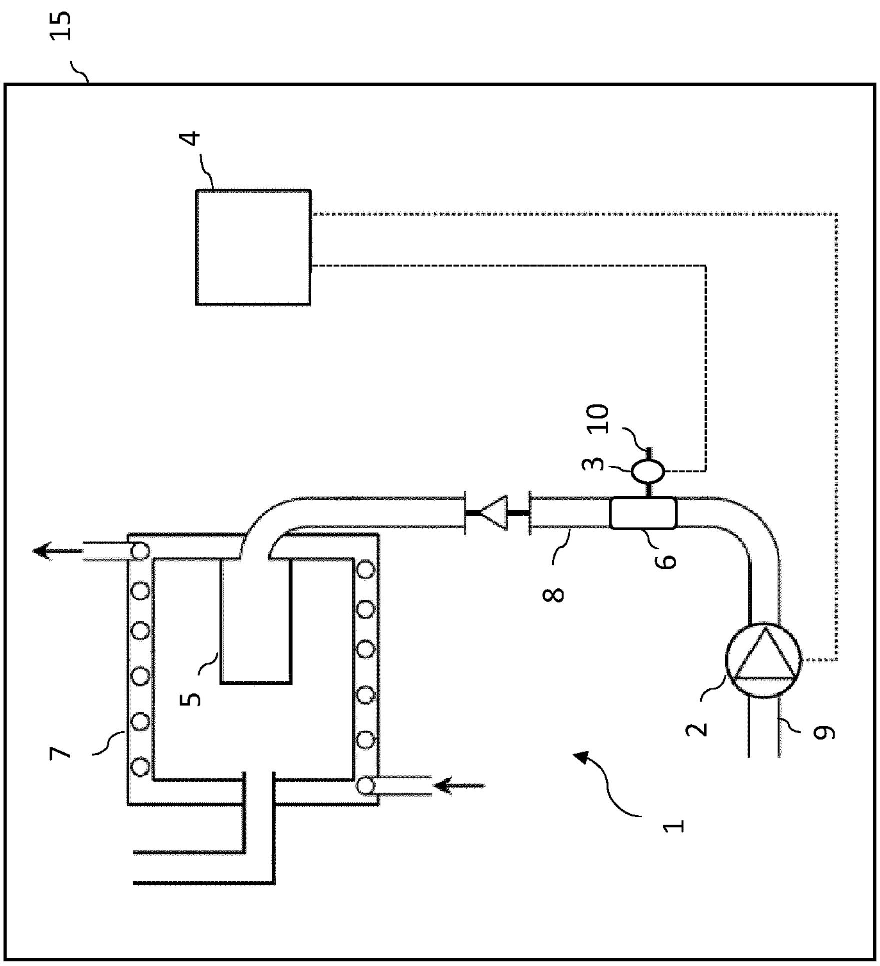


FIG. 1

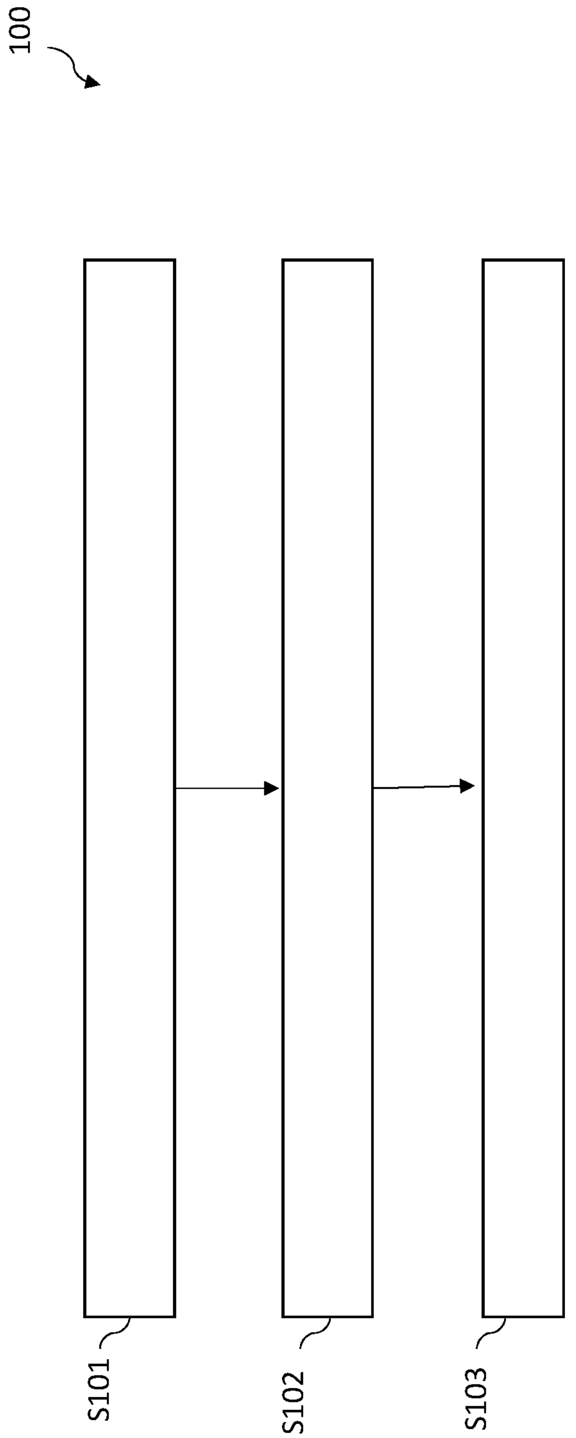
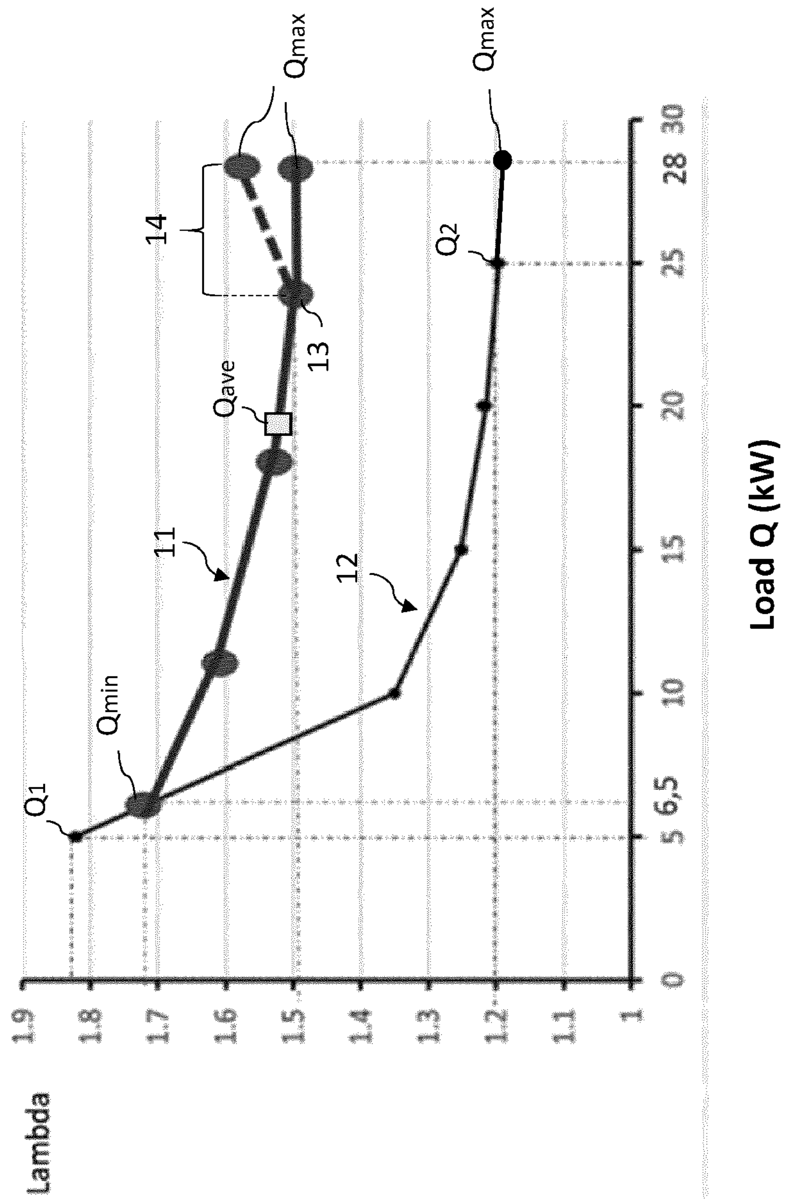


FIG. 2



Lambda
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0
5
6,5
10
15
20
25
28
30
Load Q (kW)
Q1
Qmin
Qmax
Qave
Q2
11
12
13
14

FIG. 3

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EUROPEAN SEARCH REPORT

Application Number
EP 22 18 5098

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	US 2022/163203 A1 (TEN HOEVE DIRK [NL] ET AL) 26 May 2022 (2022-05-26) * paragraphs [0001] - [0003]; claims 1-26; figures 2(a),2(b),3(a), 3(b),6-8 * * paragraph [0008] - paragraph [0027] * * paragraph [0036] - paragraph [0044] * * paragraph [0073] - paragraph [0074] * * paragraph [0076] - paragraph [0078] * * paragraph [0097] - paragraph [0102] * * paragraphs [0116], [0118] * * paragraph [0144] - paragraph [0149] * -----	1-11,13 12	INV. F23D14/02 F23N1/00 F23N5/24
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TECHNICAL FIELDS SEARCHED (IPC)

F23D
F23C
F23N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	11 January 2023	Hauck, Gunther

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