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(54) Benævnelse: **SYSTEM OG FREMGANGSMÅDE TIL BESTEMMELSE AF EN STRØMNINGSHASTIGHED AF EN VASKEVÆSKE VED ET UDSTØDNINGSGASINDLØB AF ET UDSTØDNINGSGASRENSESYSTEM AF ET MARINT FARTØJ**

(56) Fremdragne publikationer:
EP-A1- 2 703 063
EP-A1- 3 085 911
WO-A1-2014/128261

DESCRIPTION

Technical field

[0001] The application relates to the technical field of the determination of the total flow rate of the washing liquid within an exhaust gas cleaning unit, particularly at the level of the exhaust gas inlet of the exhaust gas cleaning unit, more specifically a wet scrubber system, installed in a marine vessel, the exhaust gas cleaning unit being arranged to clean the exhaust gas of one or more engines of the marine vessel.

Background

[0002] According to the MEPC.259(68) 4.4.7, 2015 "Guidelines for exhaust gas cleaning systems", the EGC (exhaust gas cleaning) unit should automatically record wash water pressure and wash water flow rate at the EGC unit's (wash water) inlet connection.

[0003] In WO 2014/128261, a particular example of a vertical scrubber for cleaning exhaust gas from a marine vessel is disclosed, in which an exhaust gas tube is substantially coaxially arranged through the bottom of a lower scrubbing chamber and is released through an exhaust gas outlet being coaxially arranged through the top of an upper scrubbing chamber. A lower scrubbing chamber deflection body is arranged above the opening of the exhaust gas tube for redirecting the exhaust gas towards the walls of the scrubber and create a turbulent gas flow, where one or more lower chamber water injectors is (are) arranged above the lower scrubbing chamber deflection body, to introduce scrubbing water, and where a lower chamber exhaust gas outlet is arranged at the top of the lower scrubbing chamber as a coaxial constriction, for withdrawing the partly scrubbed exhaust gas from the first scrubbing chamber and introducing the gas into the upper scrubbing chamber.

[0004] At present, it is known to use a flow sensor for measuring the flow rate of the washing liquid at the washing liquid inlet of a wet scrubber. To comply with the requirements as mentioned above, each of the wet scrubbers installed in the marine vessel needs to be provided with such a flow sensor for measuring this flow rate, which makes it difficult to find an appropriate location in the marine vessel for installing these flow meters since at least 5 times the diameter of the straight pipe of the wet scrubber is necessary for the proper measurement of this flow rate.

[0005] It is consequently purposeful to provide a system and a method for determining the total flow rate of the washing liquid at the inlet of a wet scrubber that is less expensive, requires less space in the marine vessel, requires less maintenance and provides more reliable results compared to the flow sensors used in the art.

Summary of the invention

[0006] A first aspect of the present application provides in a system to determine a total flow rate Q_{tot} of a washing liquid at a washing liquid inlet of an exhaust gas cleaning unit installed in a marine vessel, the exhaust gas cleaning unit comprising

- a scrubber pipe comprising an exhaust gas flowing between an exhaust gas inlet and an exhaust gas outlet;
- two or more spraying nozzles mounted at different height levels in the scrubber pipe, wherein each of the spraying nozzles is
  - adapted to spray washing liquid into the exhaust gas present in the scrubber pipe in order to clean at least part of the SO_X out of the exhaust gas; and
  - operated by a valve adapted to open and to close the respective spraying nozzle, and comprising an uppermost active spraying nozzle that is opened and activated by its respective valve;

wherein the system comprises

- at least one pressure sensor arranged to measure a pressure P applied to the uppermost active spraying nozzle, expressed in Bar; and
- a process controller
  - calculating the flow rate Q of the washing liquid flowing through each of the individual active spraying nozzles, expressed in litre per minute or m^3/h, using the formula:
    $\mathrm{Qind} = \mathrm{K} \, \mathrm{x} \sqrt{(\mathrm{P} - \textit{pressure correction} + \textit{height correction})}$,
    wherein

    ▪ K is a spraying nozzle factor depending on the type of spraying nozzle,

    ▪ the pressure correction is a correction factor of the pressure P as a function of the elevation of the respective spraying nozzle in the scrubber pipe, expressed in Bar, and

    ▪ the height correction is a correction factor of the pressure P based on the height difference between the location of the pressure sensor to the respective active spraying nozzle where the flow rate is calculated, expressed in Bar; and
  - calculating the total flow rate Q_{tot} of the washing liquid at the washing liquid inlet of the exhaust gas cleaning unit, expressed in liter per minute or m^3/h, by summing up the different flow rates Q of the washing liquid through each of the individual active spraying nozzles.

[0007] This system has the advantage that it saves a lot of space onboard of the marine vessel, it requires less maintenance and it provides in a more reliable reading. Existing systems can furthermore easily be retrofitted with this system.

[0008] In an embodiment of a system according to the application, the pressure P applied to the uppermost active spraying nozzle is the pressure of the washing liquid measured outside the scrubber pipe before the uppermost active spraying nozzle.

[0009] In an embodiment of a system according to the application, the spraying nozzles are of the spiral type.

[0010] These spraying nozzles have a high energy efficiency, are clog-resistant and have a high discharge velocity.

[0011] In an embodiment of a system according to the application, the valves operating the spraying nozzles are remotely controlled.

[0012] A second aspect of the present application provides in a method to determine a total flow rate Q_{tot} of a washing liquid at an washing liquid inlet of an exhaust gas cleaning unit installed in a marine vessel, the exhaust gas cleaning unit comprising a scrubber pipe comprising an exhaust gas flowing between an exhaust gas inlet and an exhaust gas outlet in the scrubber pipe and two or more spraying nozzles in the scrubber pipe; wherein the method comprises the steps of

- spraying washing liquid by means of two or more active spraying nozzles, that are opened and activated by a respective operable valve, and that are arranged at different heights in the scrubber pipe of the exhaust gas cleaning unit, into the exhaust gas present in the scrubber pipe for cleaning at least part of the SO_X out of the exhaust gas,
- measuring a pressure P applied to an uppermost active spraying nozzle opened and activated by its respective valve, expressed in Bar, using one or more pressure sensors;
- calculating the flow rate Q_{ind} of the washing liquid flowing through each of the separate active spraying nozzles, expressed in litre per minute, by means of a process controller using the formula:

  $\mathrm{Qind} = \mathrm{K\,x}\sqrt{(\mathrm{P} - \mathit{pressure\ correction} + \mathit{height\ correction})}$

  wherein

  ▪ K is a spraying nozzle factor depending on the type of spraying nozzle,

  ▪ the pressure correction is a correction factor of the pressure P as a function of the elevation of the respective spraying nozzle in the scrubber pipe, expressed in Bar, and

  ▪ the height correction is a correction factor of the pressure P based on the height difference between the location of the pressure sensor to the respective spraying nozzle where the flow rate is calculated, expressed in Bar;

- calculating the total flow rate Q_{tot} of the washing liquid at the washing liquid inlet of the exhaust gas cleaning unit, expressed in liter per minute or m^3/h, by means of the process controller by summing up the different flow rates Q_{ind} of the washing liquid through each of the individual active spraying nozzles.

[0013] The pressure correction is a loss in pressure due to the distance between the main delivery pipe of washing liquid to the spraying nozzle, the pressure loss in the pipe itself, the pressure loss in elbows present in the main delivery pipe of washing liquid to the spraying nozzle, etc.

[0014] In a possible method according to the application, the pressure and the height correction are determined during installation of the exhaust gas cleaning unit.

[0015] In an embodiment of a method according to the application, the method uses a system according to application as described above.

[0016] A third aspect of the present application provides in a method according to the application as described above, wherein the method is computer-implemented.

[0017] A fourth aspect of the present application provides in a computer program product comprising program code instructions for implementing a method according to the application as described above.

[0018] A fifth aspect of the present application provides in a system according to the application as described above configured for executing a method according to the application as described above.

Description of the figures

[0019]

- FIG. 1 shows a wet scrubber system provided with a system according to the application including two pressure sensors for measuring the pressure outside the scrubber pipe before the uppermost active spraying nozzle;
- FIG. 2 shows an exemplary programming bloc of a process controller for determining the total flow rate Q_{tot} of the washing liquid at the exhaust gas inlet (2) of an exemplary wet scrubber system as shown in FIG. 1, in which the pressure outside the scrubber pipe before the uppermost active spraying nozzle I is 2.1 Bar and spraying nozzles I, II, V and VI are open and thus active.

Detailed description of the invention

[0020] As can be seen in FIG. 1, the exhaust gas cleaning unit, more specifically the wet scrubber system, comprises a scrubber pipe (1) having an exhaust gas inlet (2) at the bottom thereof and an exhaust gas outlet (3) at the top thereof between which an exhaust gas is flowing. Inside the scrubber pipe (1), a number of spraying nozzles (I - VI) are arranged that are mounted at different height levels throughout the scrubber pipe (1). Each of the spraying nozzles (I - VI) are arranged to spray a washing liquid, more specifically sea water, into the exhaust gas present in the scrubber pipe (1) in order to clean at least part of, and more specifically the required amount of SO_x out of the exhaust gas. More specifically, spraying nozzles of the spiral type are used. The washing liquid is supplied from a washing liquid main pipe (6) to different washing liquid sub pipes (7) that supply the washing liquid to the each of the different spraying nozzles (I - VI) inside the scrubber pipe (1).

[0021] Each of the spraying nozzles (I - VI) are operated by a valve (a - f), more specific a butterfly valve, arranged to open and to close each of the respective spraying nozzles (I - VI). An open and thus activated spraying nozzle is also called an 'active' spraying nozzle. These valves (a - f) are remotely controlled (opened and closed) by means of one or more actuators (not shown on the figure).

[0022] Furthermore, a system is provided to determine the total flow rate Q_{tot} of the washing liquid in the washing liquid main pipe (6), which is required according to the MEPC.259(68) 4.4.7, 2015 "Guidelines for exhaust gas cleaning systems". The system therefore comprises a process controller (not shown on the figures) that is arranged to calculate the total flow rate Q_{tot} of the washing liquid in the washing liquid main pipe (6) by summing up the different individual flow rates Q_{ind} of the washing liquid to each of the individual active spraying nozzles. The process controller is therefore also arranged to calculate the flow rate Q_{ind} of the washing liquid flowing through each of the individual active spraying nozzles, using the formula:

$$\mathrm{Qind} = \mathrm{K\,x}\sqrt{(\mathrm{P} - \mathit{pressure\ correction} + \mathit{height\ correction})},$$

wherein

- P is the pressure applied upon the uppermost active spraying nozzle,
- K is a spraying nozzle factor depending on the type of spraying nozzle,
- the pressure correction is a correction factor of the pressure P as a function of the elevation of the respective spraying nozzle in the scrubber pipe, expressed in Bar, and
- the height correction is a correction factor of the pressure P based on the height difference between the location of the pressure sensor to the respective spraying nozzle where the flow rate is calculated, expressed in Bar.

[0023] In order to measure the pressure P applied upon the uppermost active spraying nozzle, the system comprises at least one pressure sensor (4). The pressure P is more specifically measured inside the washing liquid main pipe (6) outside the scrubber pipe (1) before the valve that is operating the uppermost active spraying nozzle (see FIG. 1). More in particular, two pressure sensors (4) are applied for the redundancy, i.e. if the measured pressure difference is bigger in one of these two pressure sensors (4), they need to be checked and the faulty one needs to be prepared. A pressure indicator (5) indicates the pressure P as measured by the two pressure sensors (4) (which should be the same for each of the pressure sensors (4)).

[0024] Advantageously, the pressure and the height correction are determined during installation of the wet scrubber system.

[0025] In case there is no flow of scrubber liquid through the wet scrubber, and thus the pump is stopped, the flow at the height of each of the spraying nozzles (I - VI) is zero and consequently also the total flow at the height of the inlet of the wet scrubber is zero.

[0026] The system can comprise an exhaust gas emission monitoring system arranged to provide an alarm in case the ratio of SO_2/CO_2 in the exhaust gas exceeds an alarm limit.

<u>**Example**</u>

[0027] FIG. 2 shows an exemplary programming bloc of a process controller for determining the total flow rate Q_{tot} of the washing liquid at the exhaust gas inlet (2) of an exemplary wet scrubber system as shown in FIG. 1. As can be seen in FIG. 2, the uppermost active spraying nozzle is the first spraying nozzle (I). The pressure measured at the outside of the scrubber pipe (1) before the operating valve of the first spraying nozzle (I) (I_Pressure) was 2.1 Bar. Also the second, fifth and sixth spraying nozzles (II, V and VI) were opened and thus active.

[0028] The flow rate Q_{ind} at the height of the different individual spraying nozzles is the following:

- spraying nozzle I: 1550 x √(2.1 - 0.4) = 2020.95 l/min or 121.2572 m^3/h;
- spraying nozzle II: 2552 x √(2.1 - 0.4 + 0.1) = 3423.87 l/min or 205.432 m^3/h;
- spraying nozzle V: 1752 x √(2.1 - 0.4 + 0.8185) = 2780.39 l/min or 166.8231 m^3/h;
- spraying nozzle VI: 1752 x √(2.1-0.4 + 0.9085) = 2829.63 l/min or 169.7777 m^3/h.

[0029] The total flow rate Q_{tot} of the washing liquid at the inlet of the scrubber (O_Flow) was then the sum of the individual flow rates Q_{ind} per spraying nozzle (121.2572 + 205.432 +

166.8231 + 169.7777) m^3/h or 663 m^3/h.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- WO2014128261A [0003]

Non-patent literature cited in the description

- Guidelines for exhaust gas cleaning systemsthe MEPC, 2015, vol. 259, 68- [0002]
- Guidelines for exhaust gas cleaning systemsMEPC, 2015, vol. 259, 684.4.7- [0022]

KRAV

1. System til bestemmelse af en samlet strømningshastighed Q_{tot} af en vaskevæske ved et vaskevæskeindløb af udstødningsgasrenseenhed installeret i et marint fartøj, hvor udstødningsgasrenseenheden omfatter

- et skrubberrør (1), som omfatter en udstødningsgas, der strømmer mellem et udstødningsgasindløb (2) og et udstødningsgasudløb (3);
- to eller flere sprøjtedyser (I - VI), som er anbragt i forskellige højdeniveauer i skrubberrøret (1), hvor hver af sprøjtedyserne (I - VI) er
  - indrettet til at sprøjte vaskevæske ind i udstødningsgassen, der er til stede i skrubberrøret (1), for at rense mindst en del af SO_x ud af udstødningsgassen; og
  - drevet af en ventil (a - f), der er indrettet til at åbne og lukke den respektive sprøjtedyse (I - VI),

  og omfatter en øverste aktiv sprøjtedyse, der åbnes og aktiveres af dens respektive ventil;

kendetegnet ved, at systemet omfatter

- mindst en trykføler (4), som er indrettet til at måle et tryk P påført på den øverste aktive sprøjtedyse, udtrykt i bar; og
- en processtyreenhed
  - som beregner strømningshastigheden Q_{ind} af vaskevæsken, der strømmer gennem hver af de individuelle aktive sprøjtedyser, udtrykt i liter pr. minut eller m^3/ time ved hjælp af formlen:

$$\mathrm{Qind} = \mathrm{K} \, \mathrm{x} \sqrt{(\mathrm{P} - \textit{pressure correction} + \textit{height correction})},$$

    hvor
    - K er en sprøjtedysefaktor, der er afhængig af typen af sprøjtedyse (I - VI),
    - trykkorrektionen er en korrektionsfaktor for trykket P som en funktion af højden af den respektive sprøjtedyse i skrubberrøret (1), udtrykt i bar, og
    - højdekorrektionen er en korrektionsfaktor for trykket P baseret på højdeforskellen mellem placeringen af trykføleren (4) og den respektive aktive sprøjtedyse, hvor strømningshastigheden beregnes, udtrykt i bar; og
  - som beregner den samlede strømningshastighed Q_{tot} af vaskevæsken ved vaskevæskeindløbet af udstødningsgasrenseenheden, udtrykt i liter pr. minut eller m^3/ time ved at summere de forskellige strømningshastigheder Q_{ind} af vaskevæsken gennem hver af de individuelle aktive sprøjtedyser.

2. System ifølge krav 1, hvor trykket P, som er påført den øverste aktive sprøjtedyse, er trykket fra vaskevæsken målt uden for skrubberrøret (1) før den øverste aktive sprøjtedyse.

3. System ifølge krav 1 eller 2, hvor sprøjtedyserne (I - VI) er af spiraltypen.

4. System ifølge et hvilket som helst af kravene 1 til 3, hvor ventilerne (a - f), der driver sprøjtedyserne (I - VI), fjernstyres.

5. Fremgangsmåde til bestemmelse af en samlet strømningshastighed Q_{tot} af en vaskevæske ved et vaskevæskeindløb til en udstødningsgasrenseenhed installeret i et marint fartøj, hvor udstødningsgasrenseenheden omfatter et skrubberrør (1), som omfatter en udstødningsgas, der strømmer mellem et udstødningsgasindløb (2) og en udstødningsgasudløb (3) i skrubberrøret (1) og to eller flere sprøjtedyser (I - VI) i skrubberrøret (1); hvor fremgangsmåden omfatter trinnene at

- sprøjte vaskevæske ved hjælp af to eller flere aktive sprøjtedyser, der åbnes og aktiveres af en respektive betjeningsventil, og som er anbragt i forskellige højder i skrubberrøret (1) af udstødningsgasrenseenheden ind i udstødningsgassen, som er til stede i skrubberrøret (1), for at rengøring af i det mindste en del af SO_x ud af udstødningsgassen,
- måle et tryk P, der påføres en øverste aktive sprøjtedyse, der er åbnet og aktiveret af sin respektive ventil, udtrykt i bar, ved hjælp af én eller flere trykfølere (4);
- beregne strømningshastigheden Q_{ind} af vaskevæsken, der strømmer gennem hver af de separate aktive sprøjtedyser, udtrykt i liter pr. minut, ved hjælp af en processtyreenhed ved hjælp af formlen:

$$\mathrm{Qind} = \mathrm{K\,x}\sqrt{(\mathrm{P} - \mathit{pressure\ correction} + \mathit{height\ correction})}$$

  hvor
  - K er en sprøjtedysefaktor, der er afhængig af typen af sprøjtedyse,
  - trykkorrektionen er en korrektionsfaktor for trykket P som en funktion af højden af den respektive sprøjtedyse i skrubberrøret (1), udtrykt i bar, og
  - højdekorrektionen er en korrektionsfaktor for trykket P baseret på højdeforskellen mellem placeringen af trykføleren (4) til den respektive sprøjtedyse, hvor strømningshastigheden beregnes, udtrykt i bar;
- beregne den samlede strømningshastighed Q_{tot} af vaskevæsken ved vaskevæskeindløbet til udstødningsgasrenseenheden, udtrykt i liter pr. minut eller m^3/ time ved hjælp af processtyreenhed ved at summere de forskellige strømningshastigheder Q_{ind} af vaskevæsken gennem hver af de individuelle aktive sprøjtedyser.

6. Fremgangsmåde ifølge krav 5, hvor trykket P og højdekorrektionen bestemmes under installationen af udstødningsgasrenseenheden.

7. Fremgangsmåde ifølge krav 5 eller 6, hvor fremgangsmåden anvender et system ifølge et hvilket som helst af kravene 1 til 4.

8. Fremgangsmåde ifølge et hvilket som helst af kravene 5 til 7, hvor fremgangsmåden er computerimplementeret.

9. Computerprogramprodukt som indeholder programkodeinstruktioner til implementering af en fremgangsmåde ifølge et hvilket som helst af kravene 5 til 8.

10. System ifølge et hvilket som helst af kravene 1 til 4 indrettet til at udføre en fremgangsmåde ifølge et hvilket som helst af kravene 5 til 8.

DRAWINGS

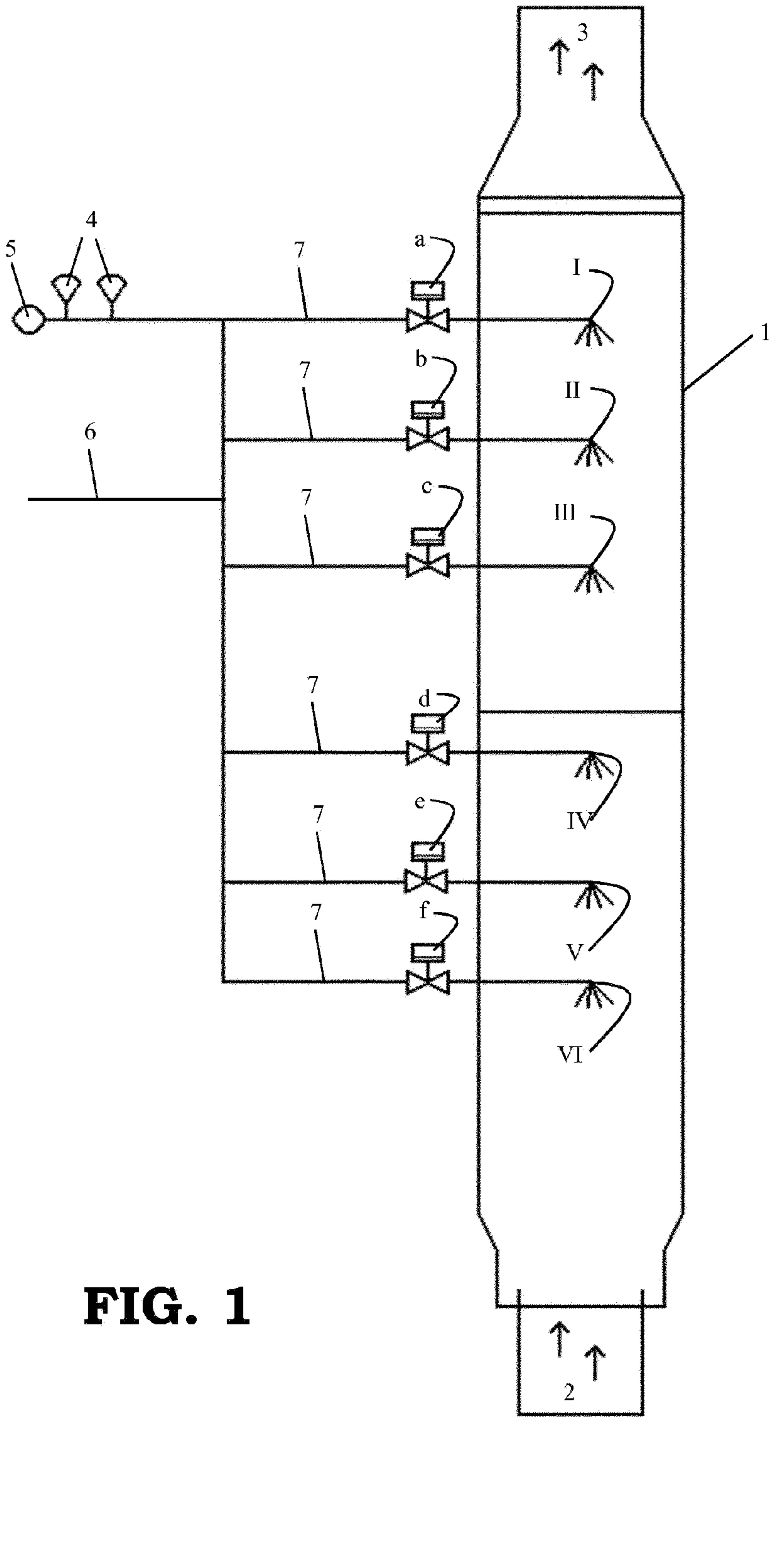
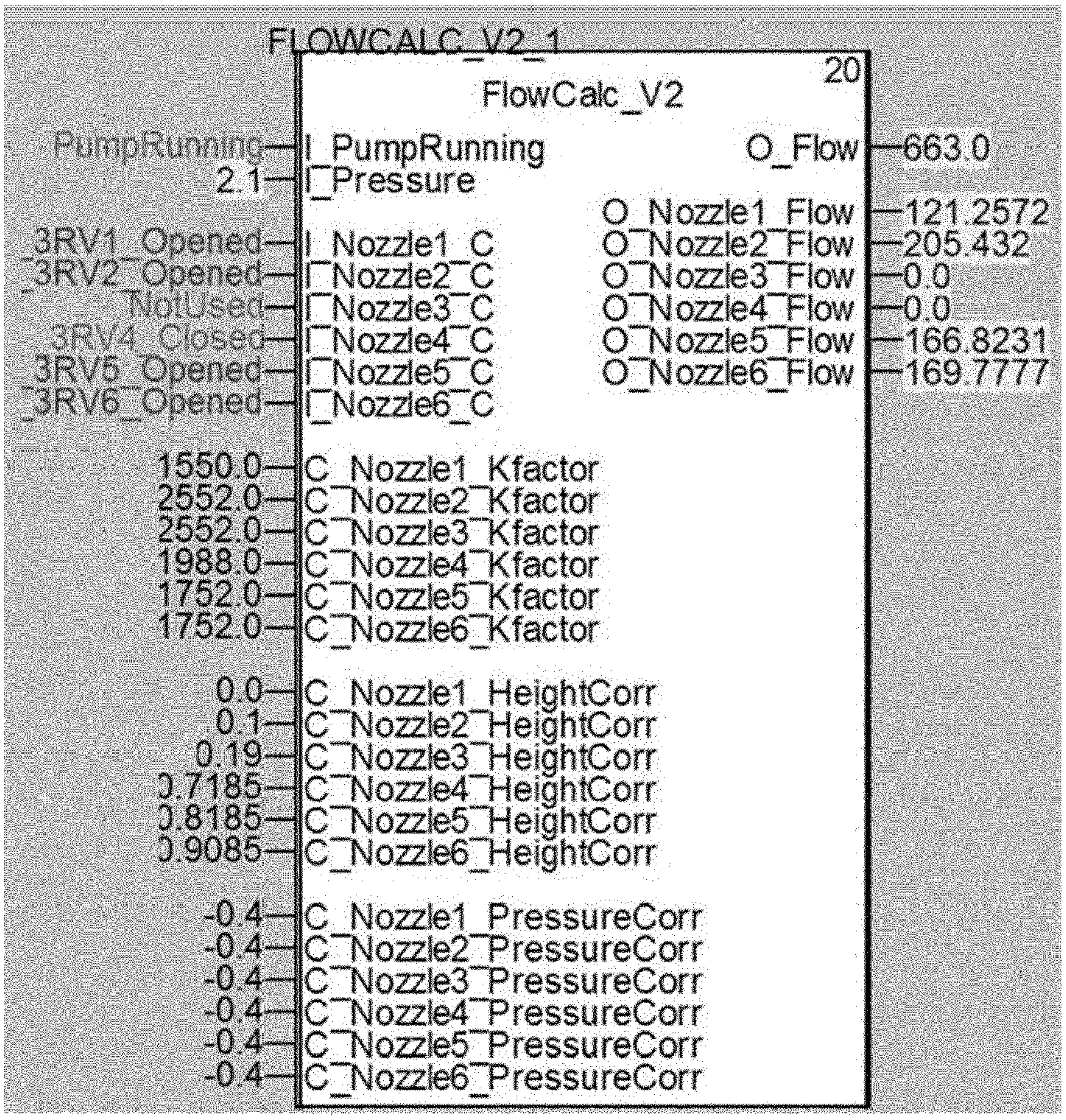


FIG. 1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2.1
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121.2572
_3RV1_Opened
I_Nozzle1_C
O_Nozzle2_Flow
205.432
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I_Nozzle5_C
O_Nozzle6_Flow
169.7777
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C_Nozzle5_Kfactor
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C_Nozzle2_HeightCorr
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C_Nozzle3_PressureCorr
-0.4
C_Nozzle4_PressureCorr
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C_Nozzle5_PressureCorr
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C_Nozzle6_PressureCorr

FIG. 2