(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 August 2016 (25.08.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/133536 A1

(51) International Patent Classification:
F23N 5/00 (2006.01) *F23R 3/00* (2006.01)
F23N 5/24 (2006.01)

(21) International Application Number:
PCT/US2015/016824

(22) International Filing Date:
20 February 2015 (20.02.2015)

(25) Filing Language: English

(26) Publication Language: English

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

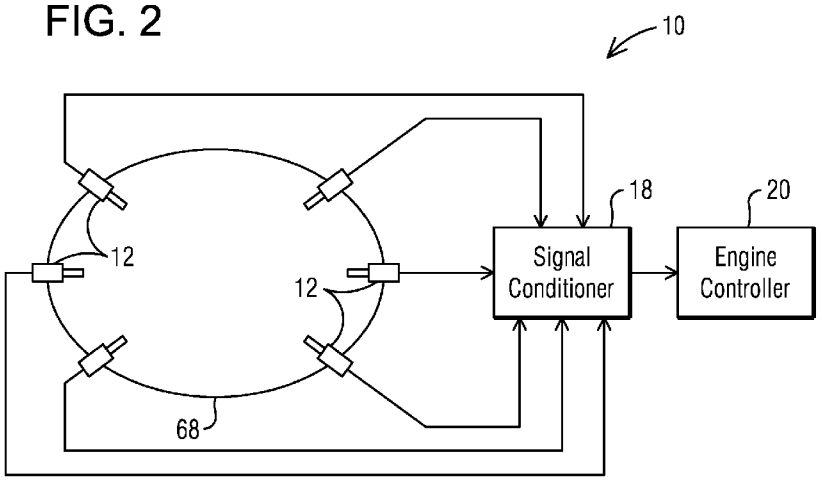
(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) Title: SYSTEM AND METHOD FOR SENSING EMISSIONS AND PROVIDING AUTOMATED CONTROL IN A COMBUSTION TURBINE ENGINE

FIG. 2



(57) Abstract: A system and method for sensing and monitoring gaseous emissions in a combustion turbine engine are provided. The system includes one or more sensors (12) configured to generate a signal indicative of concentration of emissions in a flue gas, such as may be produced in a combustor of a combustion turbine engine. In certain disclosed embodiments, a controller (20) may be coupled to receive the signal indicative of the concentration of emissions. Controller (20) may be further coupled to receive a signal indicative of a condition of combustor dynamics to generate a combustion control signal based on a combustion control strategy responsive to the concentration of emissions and the condition of combustor dynamics. This control strategy that can integrate practically in real-time knowledge of emissions conditions and combustor dynamics conditions is expected to improve control of emissions and combustor dynamics.

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SYSTEM AND METHOD FOR SENSING EMISSIONS AND PROVIDING AUTOMATED CONTROL IN A COMBUSTION TURBINE ENGINE

STATEMENT REGARDING FEDERALLY SPONSORED DEVELOPMENT

[0001] Development for this invention was supported in part by Contract No. DE-FC26-05NT42644, awarded by the United States Department of Energy. Accordingly, the United States Government may have certain rights in this invention.

BACKGROUND

[0002] 1. Field

[0003] Disclosed embodiments are generally related to sensing and monitoring gaseous emissions in a combustion turbine engine, and, more particularly, to insitu dynamic sensing and monitoring of gaseous emissions, where such insitu dynamic sensing and monitoring may be used to provide automated engine control.

[0004] 2. Description of the Related Art

[0005] The combustion of fossil fuels in a combustion turbine engine, such as in a power generation plant, produces gaseous emissions that can give rise to environmental concerns. Examples of emissions that may be of concern include carbon monoxide (CO) and nitrogen oxides (NOx). Governmental regulations make the monitoring of these and other compounds an operational requirement.

[0006] For readers desirous of general background information, see paper titled "Combustion Control and Sensors: A Review" by Nicolas Doquier and Sebastian Candel, Progress and Combustion Science 28 (2002) 107-150, providing a survey of sensor systems in connection with combustion control. See also paper titled "Technology Characterization: Gas Turbines", prepared for: Environmental Protection Agency, Washington, DC by Energy and Environmental Analysis (an ICF International Company) Arlington, Virginia, 2008, giving examples of capital expenditures that can be involved in connection with an installation of a continuous emission monitoring system (CEMS) in a gas turbine plant, where such expenditures can substantially add to the cost of the gas turbine plant.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. 1 is a schematic representation of one non-limiting embodiment of a system embodying aspects of the invention, as may include an array of sensors that may be configured for sensing emissions in a flue gas, such as may be produced in a combustor of a combustion turbine engine.

[0008] FIG. 2 is a schematic representation of another non-limiting embodiment of a system embodying further aspects of the invention, as may include a controller that may be configured for engine control, such as may involve control of combustor dynamics.

[0009] FIG. 3 is an isometric view of a casing for accommodating one or more emission sensors, where the casing may include an oxidative cap configured to reduce cross-sensitivies of the one or more sensors to a predefined gas species in the flue gas.

[0010] FIG. 4 is generally a side view of the oxidative cap shown in FIG. 3 in an unassembled condition.

[0011] FIG. 5 is block diagram representation of one non-limiting embodiment of a controller embodying aspects of the present invention.

[0012] FIG. 6 is a schematic representation of an emissions sensor including a heater responsive to a heater controller configured to adjust heater temperature based on temperature variation of the flue gas.

[0013] FIG. 7 is a simplified schematic of one non-limiting embodiment of a combustion turbine engine, such as a gas turbine engine, that can benefit from disclosed embodiments of the present invention.

DETAILED DESCRIPTION

[0014] The inventor of the present invention has recognized certain issues that can arise in the context of certain prior art emission monitoring systems, such as in applications involving combustion turbine engines. These prior art emission monitoring systems may involve a climate-controlled environment, and gas sample

extraction. Consequently such systems generally require substantial capital expenditures, such as in connection with equipment and infrastructure to form and operate the climate-controlled environment, as well as for extraction pumps and lengthy and cumbersome piping for implementing the gas sample extraction process. In addition to the high cost of installation and maintenance, these monitoring systems tend to exhibit a relatively slow response time (e.g., ranging from one to three minutes depending on the type of power plant) that is not suitable to provide dynamic active engine control. In view of such a recognition, the present inventor proposes a system and method that in a cost-effective manner can accurately and reliably sense and monitor emissions in a flue gas, as may be produced in a combustor of a combustion turbine engine. Additionally, the proposed emission monitoring system utilizes sensors having a sufficiently fast response that in one non-limiting application is effective to provide dynamic engine control.

[0015] In the following detailed description, various specific details are set forth in order to provide a thorough understanding of such embodiments. However, those skilled in the art will understand that embodiments of the present invention may be practiced without these specific details, that the present invention is not limited to the depicted embodiments, and that the present invention may be practiced in a variety of alternative embodiments. In other instances, methods, procedures, and components, which would be well-understood by one skilled in the art have not been described in detail to avoid unnecessary and burdensome explanation.

[0016] Furthermore, various operations may be described as multiple discrete steps performed in a manner that is helpful for understanding embodiments of the present invention. However, the order of description should not be construed as to imply that these operations need be performed in the order they are presented, nor that they are even order dependent, unless otherwise indicated. Moreover, repeated usage of the phrase "in one embodiment" does not necessarily refer to the same embodiment, although it may. It is noted that disclosed embodiments need not be construed as mutually exclusive embodiments, since aspects of such disclosed embodiments may be appropriately combined by one skilled in the art depending on the needs of a given application.

[0017] The terms "comprising", "including", "having", and the like, as used in the present application, are intended to be synonymous unless otherwise indicated. Lastly, as used herein, the phrases “configured to” or “arranged to” embrace the concept that the feature preceding the phrases “configured to” or “arranged to” is intentionally and specifically designed or made to act or function in a specific way and should not be construed to mean that the feature just has a capability or suitability to act or function in the specified way, unless so indicated.

[0018] FIG. 1 is a schematic representation of one-non-limiting embodiment of a system embodying aspects of the present invention. The system 10 may include one or more sensors 12 configured to generate a signal indicative of concentration of emissions in a flue gas (schematically represented by arrows 14) that may be produced in one or more combustors of a combustion turbine engine. In one non-limiting embodiment, system 10 comprises a sensor array (e.g., conceptually represented by the dashed ellipse 16 in FIG. 1) configured to generate respective signals indicative of respective concentrations of emissions. In one non-limiting embodiment, sensor array 16 is spatially distributed in an exhaust 68 of the combustion turbine engine. In one non-limiting embodiment, sensor 12 may be a solid state sensor, such as a potentiometric sensor, or a pulsed potentiometric sensor. Non-limiting examples of emissions that may be sensed by sensor 12 may comprise NOx emissions and CO emissions.

[0019] As may be appreciated in FIG. 2, a signal conditioner 18 may be coupled to receive the respective signals from the sensor array. In one non-limiting embodiment, signal conditioner 18 may be configured to calculate an average value of the respective concentrations of emissions. As may be further appreciated in FIG. 2, in one non-limiting embodiment, a controller 20 may be coupled to receive the signal (or signals) indicative of the concentration of emissions. Controller 20 may be further coupled to receive a signal indicative of a condition of combustor dynamics, such as may include an indication of combustion-driven oscillations, (e.g., thermo-acoustic instabilities), etc.

[0020] In one non-limiting embodiment, controller 20 may be configured to generate a combustion control signal (as may be used to, for example, dynamically control the respective settings of fuel/air valves that may be operatively associated

with the combustion system) based on a combustion control strategy responsive to the sensed concentration of emissions and the sensed condition of combustor dynamics. This hybrid control strategy is expected to synergistically improve control of emissions and combustor dynamics.

[0021] In one non-limiting embodiment, as may be appreciated in FIG. 5, controller 20 may include a module 22 (e.g., a comparator module) configured to compare the condition of combustor dynamics relative to a predefined threshold, and, for example, when the condition of combustor dynamics exceeds the predefined threshold, the combustion control strategy may be configured to bring the condition of combustor dynamics to be within the predefined threshold, regardless of the concentration of emissions. As will be appreciated by one skilled in the art, this may be effective to reduce the possibility of combustor dynamic conditions that otherwise could potentially lead to cracks and thermal hot-spots throughout different parts of the engine.

[0022] In one non-limiting embodiment, as may be appreciated in FIG. 3, an oxidative cap 24 (also illustrated in FIG. 4) may be disposed at an inlet of a casing 26 where one or more emission sensors may be disposed (not seen in FIG. 4). Oxidative cap 24 may be made of a porous material chosen to reduce a cross-sensitive of the sensor to a predefined gas species (e.g., CO, etc) in the flue gas. As will be appreciated by those skilled in the art, in operation, oxidative cap 24 behaves as a chemical filter relative to the undesired gas species to improve the accuracy of the emissions sensor.

[0023] In one non-limiting embodiment, as may be appreciated in FIG. 6, a heater 30 may be thermally coupled to emissions sensor 12, where heater 30 may be responsive to a heater controller 32 configured to adjust heater temperature based on temperature variation of the flue gas, as may be sensed by a thermocouple 34.

[0024] FIG. 7 is a simplified schematic of one non-limiting embodiment of a combustion turbine engine 50, such as gas turbine engine, that can benefit from disclosed embodiments of the present invention. Combustion turbine engine 50 may comprise a compressor 52, a combustor 54, a combustion chamber 56, and a turbine 58. During operation, compressor 52 takes in ambient air and provides compressed air

to a diffuser 60, which passes the compressed air to a plenum 62 through which the compressed air passes to combustor 54, which mixes the compressed air with fuel, and provides combusted, hot working gas via a transition 64 to turbine 58, which can drive power-generating equipment (not shown) to generate electricity. A shaft 66 is shown connecting turbine 58 to drive compressor 52. Disclosed embodiments of sensors embodying aspects of the present invention may be incorporated at exhaust 68 of turbine 58 to advantageously achieve reliable and cost-effective sensing of concentration of emissions in the flue gas produced in combustor 54 of the combustion turbine engine.

[0025] In operation and without limitation, disclosed embodiments are expected to provide a cost-effective, fast-responding and accurate system and methodology for sensing exhaust emissions in a combustion turbine engine. In one non-limiting application, the sensing system may be part of a combustion control system configured to dynamically generate a combustion control signal based on a hybrid combustion control strategy that may be responsive to a sensed concentration of emissions and a sensed condition of combustor dynamics, e.g., an integrated control strategy. In another non-limiting application, the sensing system may be cost-effectively used for engine testing, such as in the context of small gas turbines, where every new engine is individually tested for emissions before being deployed.

[0026] While embodiments of the present disclosure have been disclosed in exemplary forms, it will be apparent to those skilled in the art that many modifications, additions, and deletions can be made therein without departing from the spirit and scope of the invention and its equivalents, as set forth in the following claims.

What is claimed is:

1. A system comprising:

a sensor configured to generate a signal indicative of concentration of emissions in a flue gas produced in a combustor of a combustion turbine engine; and

a controller coupled to receive the signal indicative of the concentration of emissions, the controller further coupled to receive a signal indicative of a condition of combustor dynamics, wherein the controller is configured to generate a combustion control signal based on a combustion control strategy responsive to the concentration of emissions and the condition of combustor dynamics.

2. The system of claim 1, wherein the sensor comprises a sensor array configured to generate respective signals indicative of respective concentrations of emissions, wherein the sensor array is spatially distributed in an exhaust of the combustion turbine engine.

3. The system of claim 2, further comprising a signal conditioner coupled to receive the respective signals from the sensor array, wherein the signal conditioner is configured to calculate an average value of the respective concentrations of emissions.

4. The system of claim 1, wherein the sensor comprises a potentiometric sensor and the emissions are selected from the group consisting of NOx emissions and CO emissions.

5. The system of claim 1, wherein the sensor comprises a pulsed potentiometric sensor and the emissions are selected from the group consisting of NOx emissions and CO emissions.

6. The system of claim 4 or claim 5, further comprising an oxidative cap at an inlet of a casing where the sensor is disposed, the oxidative cap made of a material chosen to reduce a cross-sensitive of the sensor to a predefined gas species in the flue gas.

7. The system of claim 4 or claim 5, further comprising a heater thermally coupled to the sensor, the heater responsive to a heater controller configured to adjust heater temperature based on temperature variation of the flue gas.

8. The system of claim 1, wherein the controller comprises a module to compare the condition of combustor dynamics relative to a predefined threshold, and, when the condition of combustor dynamics exceeds the predefined threshold, the combustion control strategy is configured to bring the condition of combustor dynamics to be within the predefined threshold, regardless of the concentration of emissions.

9. A system comprising:

a sensor array configured to generate respective signals indicative of respective concentrations of emissions in a flue gas produced in a combustor of a combustion turbine engine, wherein the sensor array is spatially distributed in an exhaust of the combustion turbine engine, wherein the respective sensor comprises a solid state potentiometric sensor or a solid state potentiometric pulsed sensor and the emissions are selected from the group consisting of NOx emissions and CO emissions.

10. The system of claim 9, further comprising an oxidative cap at an inlet of a respective casing where a respective sensor of the sensor array is disposed, the oxidative cap made of a material chosen to reduce a cross-sensitive of the respective sensor to a predefined gas species in the flue gas.

11. The system of claim 9 or claim 10, further comprising a controller coupled to receive the respective signals indicative of the respective concentrations of emissions, the controller further coupled to receive a signal indicative of a condition of combustor dynamics, wherein the controller is configured to process the received signals and generate a combustion control signal based on a combustion control strategy responsive to the respective concentrations of emissions and the condition of combustor dynamics.

12. The system of claim 9, further comprising a signal conditioner coupled to receive the respective signals from the sensor array, wherein the signal conditioner is configured to calculate an average value of the respective concentrations of emissions.

13. The system of claim 9 or claim 10, further comprising a signal conditioner coupled to receive the respective signals from the sensor array, wherein the signal conditioner is configured to calculate an average value of the respective concentrations of emissions, and a controller coupled to receive the average value of the respective concentrations of emissions, the controller further coupled to receive a signal indicative of a condition of combustor dynamics, wherein the controller is configured to generate a combustion control signal based on a combustion control strategy responsive to the average value of the respective concentrations of emissions and the condition of combustor dynamics.

14. The system of claim 11 or claim 13, wherein the controller comprises a module for comparing the condition of combustor dynamics relative to a predefined threshold, and, when the condition of combustor dynamics exceeds the predefined threshold, the combustion control strategy is configured to bring the condition of combustor dynamics to be within the predefined threshold, regardless of the concentration of emissions.

15. The system of claim 9 or claim 10, further comprising a heater thermally coupled to the sensor, the heater responsive to a heater controller configured to adjust heater temperature based on temperature variation of the flue gas.

16. A method comprising:

sensing concentration of emissions in a flue gas produced in a combustor of a combustion turbine engine; and

processing in a controller a signal indicative of the concentration of emissions and a signal indicative of a condition of combustor dynamics, wherein the processing comprises generating a combustion control signal based on a combustion control strategy responsive to the concentration of emissions and the condition of combustor dynamics.

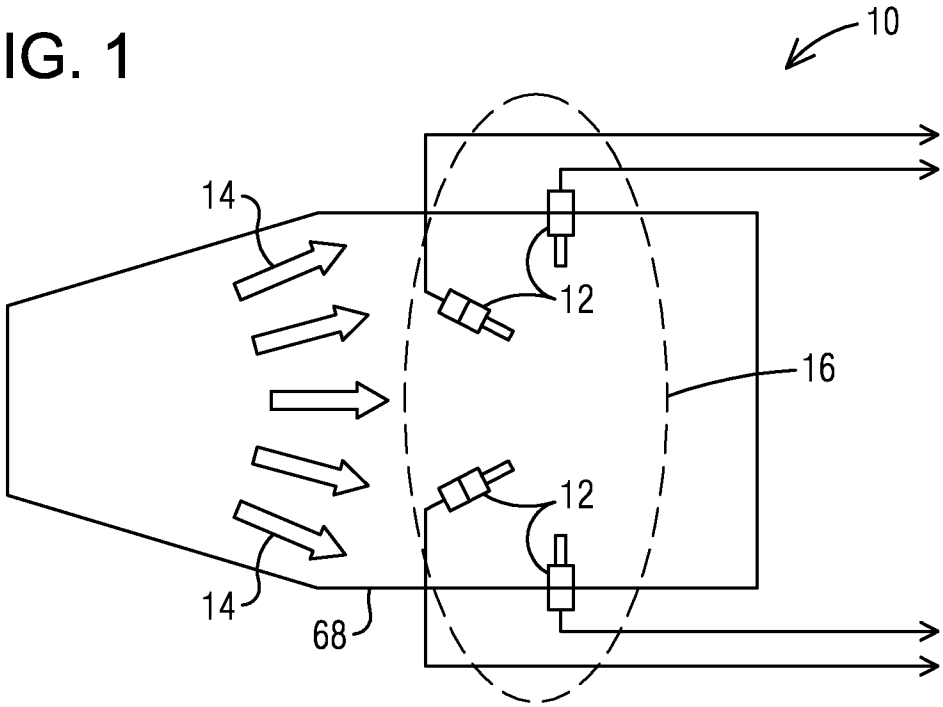
17. The method of claim 16, wherein the processing comprises comparing the condition of combustor dynamics relative to a predefined threshold, and, when the condition of combustor dynamics exceeds the predefined threshold, configuring the combustion control strategy to bring the condition of combustor dynamics to be within the predefined threshold, regardless of the concentration of emissions.

18. The method of claim 16, wherein the sensing is performed with a sensor array configured to generate respective signals indicative of respective concentrations of emissions, and further comprising spatially distributing the sensor array in an exhaust of the combustion turbine engine

19. The method of claim 16, wherein the sensing of the concentration of emissions comprises in-situ sensing of the concentration of emissions.

20. The method of claim 16, further comprising reducing a cross-sensitive of the respective sensor to a predefined gas species in the flue gas.

FIG. 1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14
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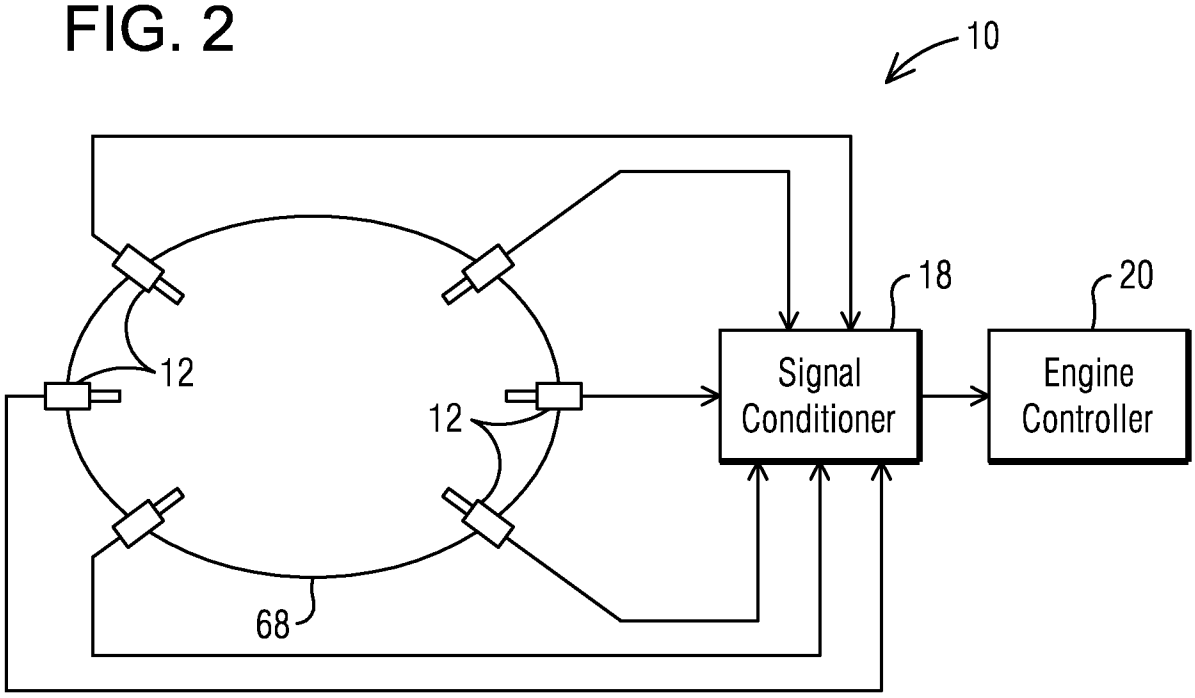
16
12
14
68

FIG. 2


10
18
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12
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Signal Conditioner
Engine Controller
68

FIG. 3

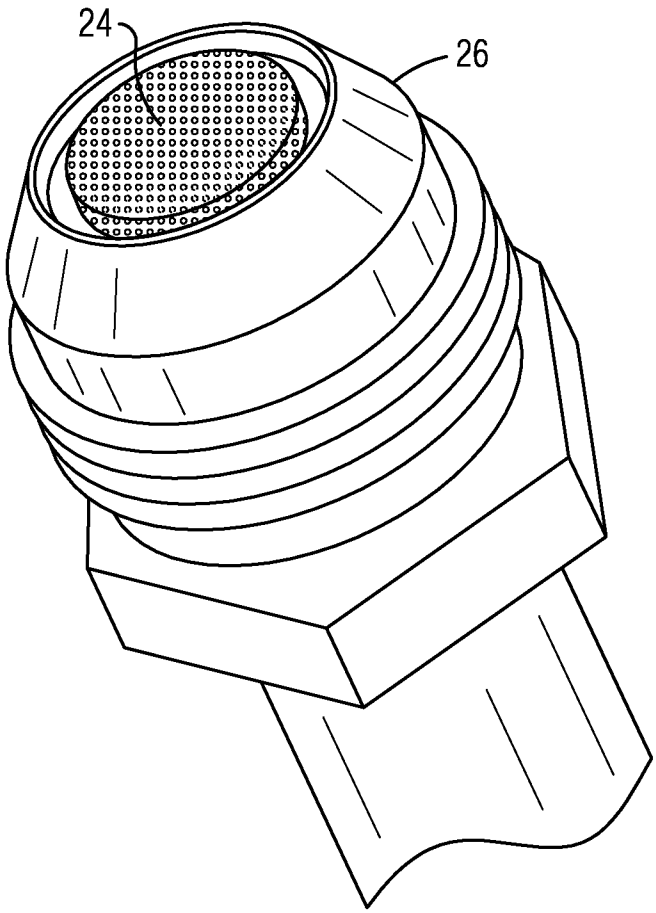


FIG. 4

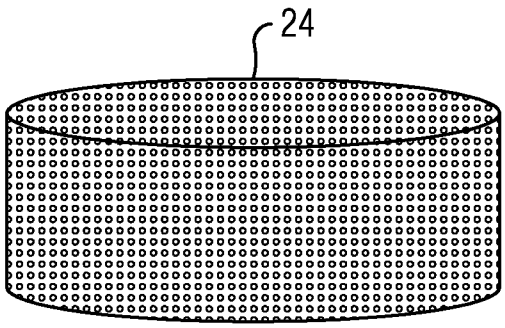


FIG. 5

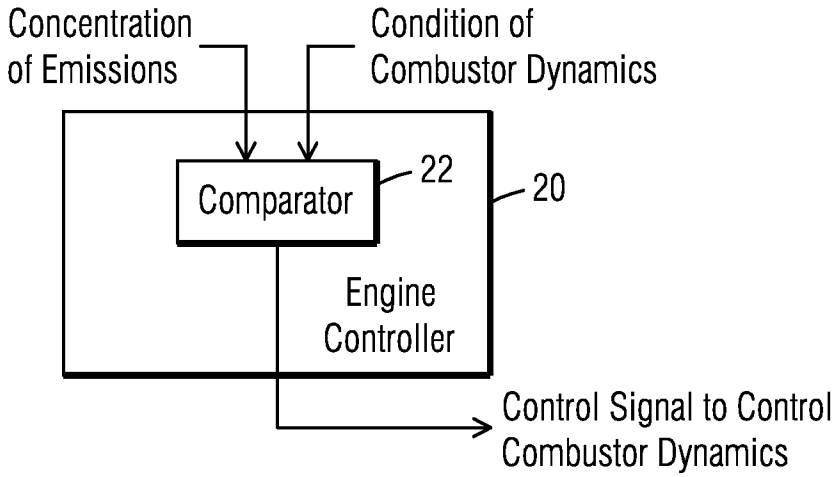


FIG. 6

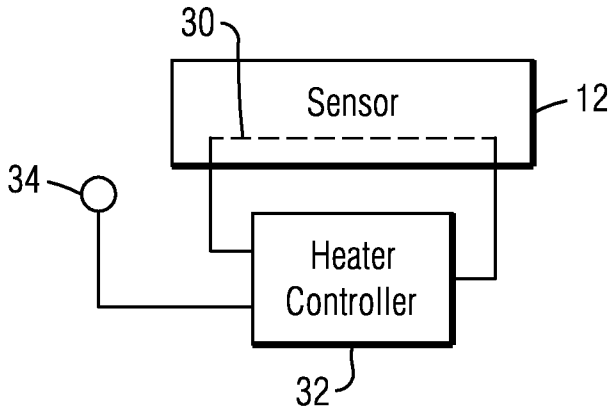
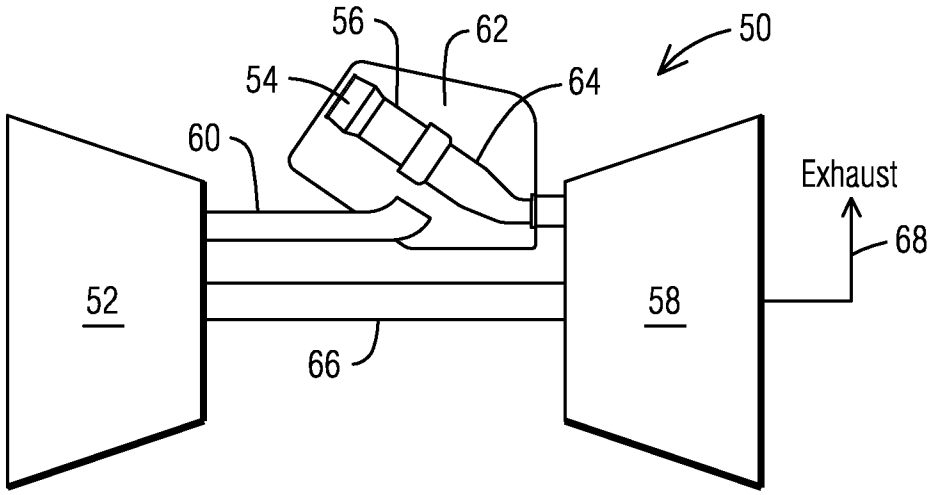


FIG. 7



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/016824

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23N5/00 F23N5/24 F23R3/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F23N F23R

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2015	23/10/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rudolf, Andreas

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Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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