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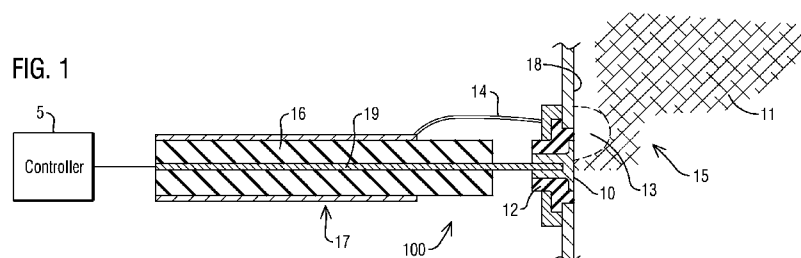
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(54) Title: SENSOR SYSTEM AND METHOD FOR DETECTING COMBUSTION ANOMALIES IN A GAS TURBINE COMBUSTOR



(57) Abstract: An ion sensor (15) is placed in a combustor that is capable of detecting irregular combustion conditions. The ion sensor (15) may be a disc or ring that is placed within the chamber wall of the combustor. Detection of ions by the ion sensor (15) can indicate that an irregular combustion event is occurring, such as a flashback. An ion sensor may also be located on an igniter (31) to determine whether or not an igniter (31) has been lit or is in danger of failing.



SENSOR SYSTEM AND METHOD FOR DETECTING COMBUSTION ANOMALIES
IN A GAS TURBINE COMBUSTOR

BACKGROUND

1. Field

- 5 [0001] Disclosed embodiments are generally related to gas turbine combustors and, more particularly, to sensors used with gas turbine combustors.

2. Description of the Related Art

- [0002] One of the problems with running gas turbine combustors tuned for low
10 emissions is the increased possibility of getting combustion anomalies such as flashbacks or lean blow outs. These anomalies can occur more frequently due to the gas turbine combustors running at very lean conditions. These anomalies can be harmful to the combustor units as well as to the safety of the operators. While flashback sensors have previously been proposed they have not been effective in fully
15 detecting the onset of a flashback event. For example, thermocouple sensors have been used; however they have relatively slow reactions times. Also, these types of sensors only protect a highly localized area.

- [0003] Other types of sensors beside thermocouple sensors have been used for flashback detection. However they have been incorporated into the support housing of
20 combustor baskets, such as on the fuel rockets of a combustor. Although this is an astute way of implementing sensors, doing makes the combustor basket cumbersome and prohibitively costly. Further, the sensing range of the sensors is very limited thereby reducing the overall efficiency of a flashback detection event. The resulting sensors function as point sensors having a limited range of only a few millimetres. In
25 practice these sensors are as effective or on par with thermocouple sensors for detecting flashback. Therefore there is a need to reliably and quickly detect and warn operators about these anomalies in the gas turbine combustor.

- [0004] Also important in the continuous operation of gas turbine combustors is monitoring of the flame igniter's health over time. Monitoring of a flame igniter's

health can insure that gas turbine combustors are not needlessly taken offline due to false readings. Such detection of fail rates has become an increasingly important problem as the current failure rate of igniters has increased.

[0005] Therefore there is a need for sensors that are able to address combustion
5 anomalies and ignition issues within gas turbine combustors.

SUMMARY

[0006] Briefly described, aspects of the present disclosure relate to combustor sensor systems.

10 [0007] An aspect of the disclosure provides a sensor system having an ion sensor locatable within a combustor for detecting anomalies in a combustor, wherein the ion sensor comprises an electrode and an insulator surrounding the electrode, wherein the ion sensor detects ions substantially throughout a chamber of the combustor. The system also has a controller operably connected to the ion sensor.

15 [0008] Another aspect of the disclosure provides a sensor system having an ion sensor locatable on an igniter used with combustors, wherein the ion sensor comprises an electrode and an insulator. The system also has a controller operably connected to the ion sensor.

[0009] Still yet another aspect of the disclosure is a sensor system having an ion
20 sensor locatable within a combustor, wherein the ion sensor comprises an electrode and an insulator, wherein the ion sensor generates an electric field that extends greater than 5 mm from a surface of the ion sensor. The system also has a controller operably connected to the ion sensor.

BRIEF DESCRIPTION OF THE DRAWINGS

25 [0010] Fig. 1 shows a cross-sectional view of a combustor ion sensor system in accordance with an embodiment of the present invention.

[0011] Fig. 2 is a view of the combustor ion sensor system shown in Fig. 1 as seen

from the combustion chamber.

[0012] Fig. 3 shows a cross-sectional view of a combustor ion sensor system in accordance with another embodiment of the present invention.

[0013] Fig. 4 is a view of the combustor ion sensor system shown in Fig. 3 as seen
5 from the combustion chamber.

[0014] Fig. 5 is a view of the combustor from the combustion chamber.

[0015] Fig. 6 is flow chart showing a method for detecting ions in a combustor.

[0016] Fig. 7 is a view of a combustor ion sensor system in accordance with another embodiment of the present invention.

10 [0017] Fig. 8 is a view of an igniter used in the combustor ion sensor system shown in Fig. 7.

[0018] Fig. 9 is an alternative embodiment of a combustor ion sensor system used with an igniter.

[0019] Fig. 10 is another alternative embodiment of a combustor ion sensor system
15 used with an igniter.

[0020] Fig. 11A is a circuit diagram useable in the combustor ion system shown in any one of Figs. 7-9.

[0021] Fig. 11B are graphs of current versus time of the exemplary current and measured current from the igniter and circuit shown in Fig. 11A.

20 [0022] Fig. 12 is a flow chart showing the method for determining the status of an igniter.

DETAILED DESCRIPTION

[0023] To facilitate an understanding of embodiments, principles, and features of the present disclosure, they are explained hereinafter with reference to implementation in illustrative embodiments. Embodiments of the present disclosure, however, are not limited to use in the described systems or methods.

5 [0024] The components and materials described hereinafter as making up the various embodiments are intended to be illustrative and not restrictive. Many suitable components and materials that would perform the same or a similar function as the materials described herein are intended to be embraced within the scope of embodiments of the present disclosure.

10 [0025] An embodiment of the present disclosure sets forth a gas turbine combustor that employs ion sensors that provide reliable detection of a combustion anomaly, e.g. flashback, etc. A gas turbine combustor may be constructed with a combustor ion sensor system in place. In some instances, a combustor ion sensor system in accordance with the present disclosure can be achieved by providing a modification to
15 the gas turbine combustor. The modification can provide more coverage and faster response time for sensing combustion anomalies than that which is found in previous combustors. Another embodiment of the present invention can employ the same sensor principles in order to provide reliable monitoring of the flame igniter's performance and provides information on its health that can warn the operator or
20 customer of a future failure of the combustor's igniter system.

[0026] Now referring to the drawings wherein embodiments of the present invention are shown, Fig. 1 shows a cross-sectional view of combustor ion sensor system 100 located within a combustor. The combustor ion sensor system 100 is able to provide sensing of the ion discharge from a combustor flame 11. When a threshold
25 level of ions is sensed the combustor ion sensor system 100 is able to take measures to protect components of the combustor from an irregular combustion output, such as a flashback occurrence. Because an ion sensor system 100 is being used measures may be taken quicker than with other sensor systems, thus potentially preserving more of the system.

30 [0027] In practice the combustor ion sensor system 100 is able to take a baseline

measurement of the ions discharged from a combustor during typical operation. The baseline measurement can be used to establish a threshold level. The baseline may be obtained at a time when the combustor is operating properly without any apparent adverse effects. The range of the baseline may also be the sensor signal measured at
5 different loads with a factor of safety. For example, 150 % of the measured signal can be used as the baseline. The baseline may also be established during initial testing of the combustor. Also, the baseline may be established, or re-established at various times during the operation of the combustor. This is used to establish the threshold. If the threshold is exceeded the fuel to the combustor can be withdrawn, or the
10 combustor otherwise shut down prior to any potential damage occurring. Alternatively, the combustor ion sensor system 100 can operate by detecting a specific metric related to the ions detected, such as change in number of ions detected, rate of change in number of ions detected, etc. The combustor ion sensor system 100 may also function without first establishing a threshold level and may simply detect
15 any increase in the ions sensed and thus take action to protect the combustor upon detection of ions.

[0028] Figs. 1 and 2 show the combustor ion sensor system 100 having a controller 5, an electrode 10, an electrode insulator 12 and a cable 17. The electrode 10 and electrode insulator 12 comprise the ion sensor 15. The electrode 10 can be located on
20 or integrated into the chamber wall 18. Surrounding the electrode 10 is an electrode insulator 12 which separates the electrode 10 from the chamber wall 18. The chamber wall 18 is grounded via ground wire 14. The ion sensor 15 is located behind the direction in which the combustor flame 11 is directed in order to detect a combustion anomaly, such as flashback. The electrode 10 may be made of any material suitable
25 for detecting ions in this environment. The electrode insulator 12 may be made of any material suitable for insulating the electrode 10, such as any type of high temperature material such as alumina, SiC based materials or ceramics, e.g. Al_2O_3 .

[0029] In the embodiment shown in Figs. 1 and 2 the ion sensor 15 forms a disc shape with the electrode 10 in the center of the disc and the electrode insulator 12
30 surrounding the electrode 10. The disc shape of the ion sensor 15 enables the generation of an electric field 13 and greater ability to detect ions generated by the combustor flame 11, such as OH and CH ions, than point sensors. The disc may have

a diameter of between 115%-125% of the allowable distance that a flame could come near the back surface of a combustor without increasing its temperature beyond a critical design temperature for the ion sensor 15 or exceeding the threshold level. For example the diameter of the sensor may be greater than 5 mm, or preferably greater than 10 mm. However, it should be understood that the diameter of an ion sensor 15, that is disc shaped may tailored for the size and shape of the combustor that is used. The increased ability to detect ions is due to the larger surface area provided by disc shaped electrode 10 and the role the larger surface area plays in generating the electric field 13. The electric field 13 enables a sensing range of greater than 5 mm and preferably greater than 10 mm from the surface of the electrode 10. The sensing range is the radius, or largest distance of the field extending from the ion sensor 15. For example, to obtain a sensing range of greater than 10 mm an ion sensor 15 that is disc shaped would have a diameter of 11.5 to 12.5 mm.

[0030] Other geometries for the electrode 10 may be used as well, such as rectangular, oval, polygonal, or irregular shaped. The disc shaped geometry of electrode 10 makes it easier to retrofit existing combustors and work within existing systems. It should be understood that while one ion sensor 15 is shown in Fig. 1, more than ion sensor 15 may be used in the combustor.

[0031] The electrode 10 is connected to a cable 17, which in the embodiment shown, is a coaxial cable comprising a wire 19 and insulator 16 surrounding the wire 19. Contact 21 shown in Fig. 2 shows where wire 19 contacts the electrode 10. The cable 17 provides the voltage and receives the signal from the ion sensor 15. The cable 17 may carry the signal to a controller 5 where the signal can be used in order to determine whether or not measures should be taken to respond to the combustion anomaly. For example, the controller 5 may determine that fuel should cut off to prevent further combustion. Controller 5 may be a processor, circuit component, distributed network, or other component that is capable of providing the logic that governs the combustor ion sensor systems.

[0032] Figs. 3-5 show combustor ion sensor system 200, which is an alternative embodiment of the system shown in Figs. 1 and 2. In combustor sensor system 200 the electrode 20 forms a continuous ring around the circumference of the combustor.

Surrounding electrode 20 is insulator 22, which together form the ion sensor 25. The ion sensor 25 is located behind the direction in which the combustor flame 11 is directed.

[0033] The continuous ring is shown in Fig. 5, where the pilot nozzle 24 and main
5 nozzles 26 of the combustor are also shown. While the electrode 20 is formed as a continuous ring, it should be understood that the ring need not be continuous and may instead, for example, include a number of electrodes that are electrically connected around the circumference of the combustor.

[0034] Similar to combustor ion sensor system 100 shown in Figs. 1 and 2,
10 combustor ion sensor system 200 is able to detect the ions that are emitted during a flashback scenario in a combustor. This is accomplished by the increased electric field and ability to detect ions over a greater area than that which is provided by point sensors or thermo-coupled sensors.

[0035] Now turning to Fig. 6, a flow chart showing the method for detecting the
15 ions generated by combustion anomalies is shown. In practice, the combustor ion sensor systems 100 and 200 generate an electric field 19 using the ion sensors 15 or 25. The electric field 19 extracts charges from the flame. During operation as long as the rate of charge extraction is small compared to the ionization rate in the flame, the flame remains quasi-neutral. An electric current flow is established between the
20 sensors 15 or 25 and the flame.

[0036] In step 251, the combustor ion sensor systems 100, or 200 detects ions emitted during combustion. As discussed above this occurs when ions emitted by the combustion process enter the electric field 13 generated by the ion sensors 15 or 25. In step 252 the detected ions are compared to a threshold level of ions. The threshold
25 level of ions may be a predetermined threshold set. For example the threshold may be preset level of ions, or a preset determination of the change in rate of ions detected. In step 253, the combustion anomaly is stopped in response to the detected ions. For example the fuel level being supplied to the combustor may be adjusted.

[0037] Now referring to Figs. 7-10, shown is combustor ion sensor system 300. In

the application of the combustor ion sensor system 300 the ion sensors 35 are used with an igniter 31 which is located within the housing 36 in Fig. 7. In combustor ion system 300 an electrode 30a, 30b or 30c is located proximate to the ignition electrode 34. The electrodes 30a, 30b or 30c are used as part of the ion sensor 35, which can include an insulator 32 and cable 17 connected to the electrode 30a, 30b, or 30c. The ion sensor 35 may also be referred to colloquially as “penny” or “stripe” sensors.

[0038] In Fig. 8, electrode 30a is shown to be oval shaped and located on the exterior of the cylindrical housing 33 of the igniter 31. In Fig. 9, electrode 30b is shown to be located on the tip 37 of the igniter 31 adjacent, or near to the ignition electrode 34. The closer the ion sensor 35 is to the tip 37 of the igniter 31 the better it is for detection of ions. In Fig. 10, electrode 30c is shown to be located as a ring encircling the circumference of the tip 37 of the igniter 31. While electrode 30c is shown to be a continuous, it is possible to provide an electrically connected ring of electrodes. The electrode 30c in Fig. 10 can provide a stronger signal with a larger detection zone than the electrodes 30a and 30b. While various geometries are shown for the electrodes in Figs. 8-10, it should be understood that other geometries may be employed.

[0039] Similar to the other combustor ion sensor systems described herein, the combustor ion sensor system 300 is able to detect ions being emitted, in this instance from the igniter 31. In particular, in the case of a lean blow out, the ion sensor 35 will provide a drop in signal due to lack of ions because of a blown out flame. Also, the ion sensing time series signal can be analyzed in real time in the frequency domain. This is in part due to the ability of the ion sensing signal capable of being monitored at very high frequencies, such as for example frequencies in excess of 20 Khz. Analyzing the time series signal can provide accurate information on a blown out flame by the shift and/or disappearance of certain frequency bands.

[0040] The response time of the ion sensor 35 is in milliseconds or faster as the sensor 35 measures the current. Additionally, the ion sensor 35 is also able to monitor the health of the igniter 31 by periodically comparing the ions detected to the previously measured ions from the igniter 31. The measurement of the ionization strength can determine when there is potentially imminent failure of the igniter 31.

[0041] Fig. 11A shows a circuit diagram that may be used in exemplary embodiments of the ion sensor system 300 and a graph. By using the circuit diagram shown in Fig. 11A an additional circuit is created using the same components of the igniter 31 to measure the intensity of the spark of the igniter 31. Fig. 11B shows an exemplary graph illustrating the current of the igniter 31 and the measured current of the igniter 31 that is processed by the controller 5. Fig. 11A shows controller 5 and igniter 31 connected in a circuit having circuit components, resistors 41, capacitors 42, amplifiers 43 and inductors 44. Inductors 44 are used to create a stepped up Fourier transform function. Now turning to Fig. 12, a flow chart showing the method for determining the status of the igniter 31 in the combustor is shown. In practice, the combustor ion sensor system 300 generates an electric field using the ion sensors 30a, 30b or 30c which is used to detect ions.

[0042] In step 351, a baseline level of the ions emitted by the igniter 31 is established. The baseline level may be stored at the controller 5. The signal from the ion sensor 35 may be baselined using a fully functional operating signal from an igniter 31. In addition to frequency monitoring, several other features of the frequency domain may be analyzed. This can be done by correlating (e.g by providing a similarity analysis) the baselined signal with the currently received signal. The correlation function will drop as the igniter gets older or functions in a progressively poorer manner. The correlation function will provide information on the health of the igniter 31 as well as, for example, a drop in intensity of the igniter 31 and misfiring of the igniter 31. In step 352 ions emitted from the igniter 31 are detected, providing the currently received signal. In step 353 the status of the igniter 31 is determined based on the emitted ions. The status determination may be done periodically or continuously. The detected levels of ions may be compared to previously detected levels of ions in order to establish the health of the igniter 31, using, for example the correlation function discussed above. The determination of status may be done by the controller 5. The status of the igniter 31 may be selected statuses such as near failure, need of maintenance or failure to ignite. Thus the determined threshold can provide early indication to an operator that the igniter 31 is in need of maintenance. The ion sensor 30a, 30b or 30c can also be used to ensure that the igniter 31 is still lit thereby preventing needlessly shutting down a combustor

due to false readings of the combustor being lit.

[0043] 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.

5

What is claimed is:

1. A sensor system (100, 200) comprising:
an ion sensor (15, 25) locatable within a combustor for detecting
5 anomalies in a combustor, wherein the ion sensor (15, 25) comprises an electrode (10, 20) and an insulator (12, 22) surrounding the electrode (10, 20), wherein the ion sensor (10, 20) detects ions substantially throughout a chamber of the combustor; and
a controller (5) operably connected to the ion sensor (15, 25).
- 10 2. The sensor system (100, 200) of claim 1, wherein the ion sensor (15, 25) is integrally located within a chamber wall (18) of the combustor.
3. The sensor system (100) of claims 1 or 2, wherein the electrode (10) is disc shaped.
- 15 4. The sensor system (100) any one of claims 1-3, wherein the electrode (10) has a diameter greater than 5 mm.
5. The sensor system (200) of any one of claims 1 or 2, wherein the ion sensor
20 (25) extends around the circumference of the chamber formed by the chamber wall (18).
6. The sensor system (200) of any one of claims 1, 2 or 5, wherein the ion sensor
25 (25) extends continuously around the circumference of the chamber formed by the chamber wall (18).
7. A method for detecting an anomaly in a combustor using the sensor system
(100, 200) of any one of claims 1-6, further comprising;
detecting ions emitted from the combustor;
30 comparing the detected ions to a threshold level; and
stopping the combustion anomaly in response to the detected ions.

8. The method of claim 7, wherein the anomaly is a flashback.
9. A sensor system (300) comprising:
an ion sensor (35) locatable on an igniter (31) used with combustors,
5 wherein the ion sensor (35) comprises an electrode (30a, 30b, 30c) and an insulator (32); and
a controller (5) operably connected to the ion sensor (35).
10. The sensor system (300) of claim 9, wherein the ion sensor (35) is
10 located on a cylindrical housing (33) of the igniter (31).
11. The sensor system (300) of claim 9, wherein the ion sensor (35) is
located on a tip (37) of the igniter (31).
12. A method for detecting an anomaly in the combustor using the sensor
15 system (300) of any one of claims 10-11, further comprising:
setting a baseline for ions emitted from the igniter (31);
detecting ions emitted from the igniter (31); and
determining a status of the igniter (31) based on the detecting of ions
20 emitted from the igniter (31).
13. The method of claim 12, wherein the status is selected from the group
consisting of near failure, need of maintenance and failure to ignite.
14. A sensor system (100, 200, 300) comprising:
an ion sensor (15, 25, 35) locatable within a combustor, wherein the
ion sensor (15, 25, 35) comprises an electrode (10, 20, 30) and an insulator, wherein
the ion sensor (15, 25, 35) generates an electric field greater than 5 mm from the
surface of the ion sensor (15, 25, 35), and
25 a controller (5) operably connected to the ion sensor (15, 25, 35).
30
15. The sensor system (100, 200) of claim 14, wherein the ion sensor (15, 25) is
integrally located within a chamber wall (18) of the combustor.

16. The sensor system (100) of any one of claims 15 and 16, wherein the electrode (10) is disc shaped.

5 17. The sensor system (100) of any one of claims 14 to 16, wherein the electrode (10) has a diameter greater than 5mm.

18. The sensor system (200) of any one of claims 14 or 15, wherein the ion sensor (25) extends around the circumference of a chamber formed by the chamber wall (18).

10

19. The sensor system (300) of claim 14, wherein the ion sensor (35) is located on an igniter (31).

20. The sensor system (300) of any one of claims 14 or 19, wherein the ion sensor
15 (31) is located on a cylindrical wall (18) of the igniter (31).

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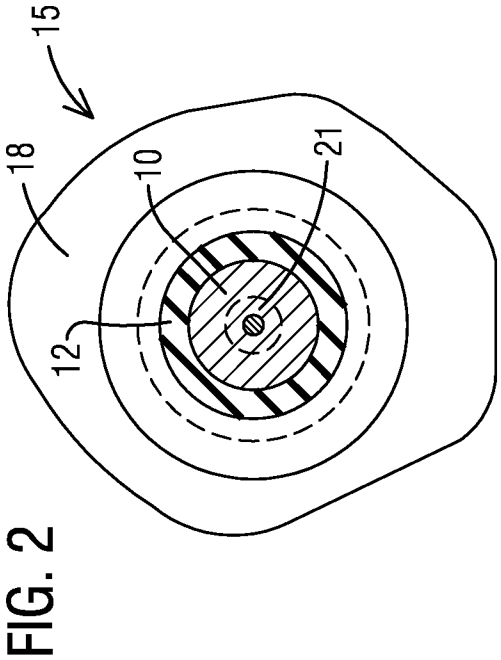
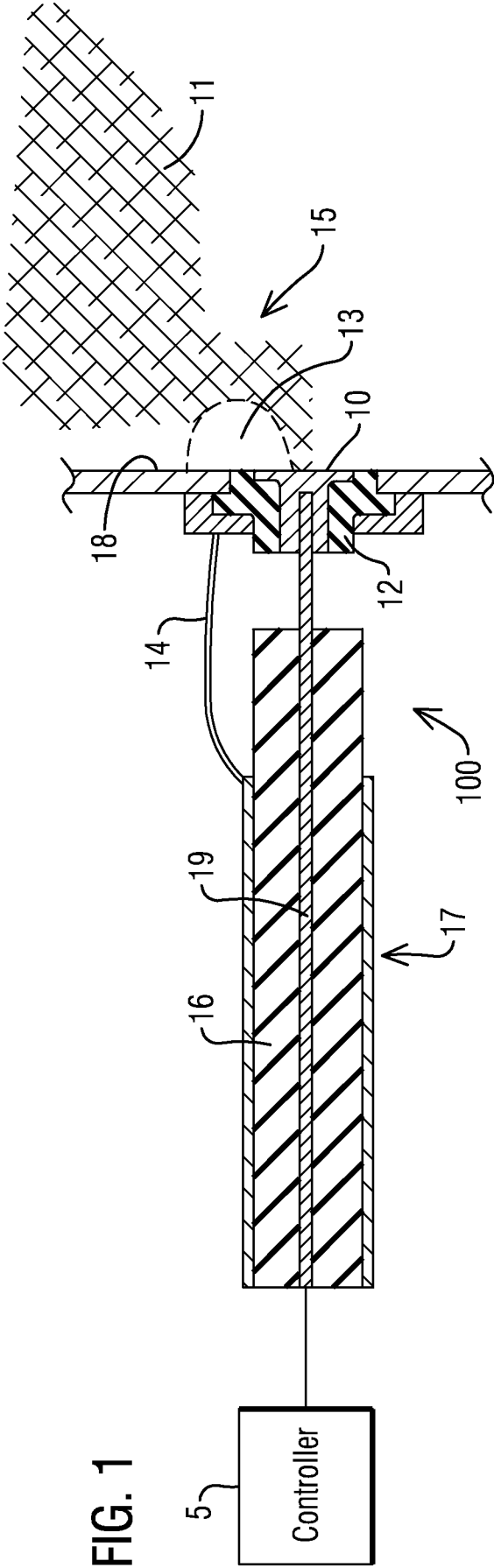
AMENDED CLAIMS
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1. A sensor system (100, 200) comprising:
an ion sensor (15, 25) locatable within a combustor for detecting anomalies in a combustor, wherein the ion sensor (15, 25) comprises an electrode (10, 20) and an insulator (12, 22) surrounding the electrode (10, 20), wherein the insulator is made of a material, wherein the ion sensor (10, 20) detects ions substantially throughout a chamber of the combustor; and
a controller (5) operably connected to the ion sensor (15, 25).
2. The sensor system (100, 200) of claim 1, wherein the ion sensor (15, 25) is integrally located within a chamber wall (18) of the combustor.
3. The sensor system (100) of claims 1 or 2, wherein the material of the insulator is selected from the group consisting of alumina, SiC based materials and ceramics.
4. The sensor system (100) any one of claims 1-3, wherein the electrode (10) has a diameter greater than 5 mm.
5. The sensor system (200) of any one of claims 1 or 2, wherein the ion sensor (25) extends around the circumference of the chamber formed by the chamber wall (18).
6. The sensor system (200) of any one of claims 1, 2 or 5, wherein the ion sensor (25) extends continuously around the circumference of the chamber formed by the chamber wall (18).
7. A method for detecting an anomaly in a combustor using the sensor system (100, 200) of any one of claims 1-6, further comprising;
detecting ions emitted from the combustor;
comparing the detected ions to a threshold level; and

stopping the combustion anomaly in response to the detected ions.

8. The method of claim 7, wherein the anomaly is a flashback.
9. A sensor system (300) comprising:
 - an ion sensor (35) locatable on an igniter (31) used with combustors, wherein the ion sensor (35) comprises an electrode (30a, 30b, 30c) and an insulator (32); and
 - a controller (5) operably connected to the ion sensor (35).
10. The sensor system (300) of claim 9, wherein the ion sensor (35) is located on a cylindrical housing (33) of the igniter (31).
11. The sensor system (300) of claim 9, wherein the ion sensor (35) is located on a tip (37) of the igniter (31).
12. A method for detecting an anomaly in the combustor using the sensor system (300) of any one of claims 10-11, further comprising:
 - setting a baseline for ions emitted from the igniter (31);
 - detecting ions emitted from the igniter (31); and
 - determining a status of the igniter (31) based on the detecting of ions emitted from the igniter (31).
13. The method of claim 12, wherein the status is selected from the group consisting of near failure, need of maintenance and failure to ignite.
14. A sensor system (100, 200, 300) comprising:
 - an ion sensor (15, 25, 35) locatable within a combustor, wherein the ion sensor (15, 25, 35) comprises an electrode (10, 20, 30) and an insulator, wherein the insulator is made of a material, wherein the ion sensor (15, 25, 35) generates an electric field greater than 5 mm from the surface of the ion sensor (15, 25, 35), and
 - a controller (5) operably connected to the ion sensor (15, 25, 35).

15. The sensor system (100, 200) of claim 14, wherein the ion sensor (15, 25) is integrally located within a chamber wall (18) of the combustor.
16. The sensor system (100) of any one of claims 15 and 16, wherein the material of the insulator is selected from the group consisting of alumina, SiC based materials and ceramics.
17. The sensor system (100) of any one of claims 14 to 16, wherein the electrode (10) has a diameter greater than 5mm.
18. The sensor system (200) of any one of claims 14 or 15, wherein the ion sensor (25) extends around the circumference of a chamber formed by the chamber wall (18).
19. The sensor system (300) of claim 14, wherein the ion sensor (35) is located on an igniter (31).
20. The sensor system (300) of any one of claims 14 or 19, wherein the ion sensor (31) is located on a cylindrical wall (18) of the igniter (31).



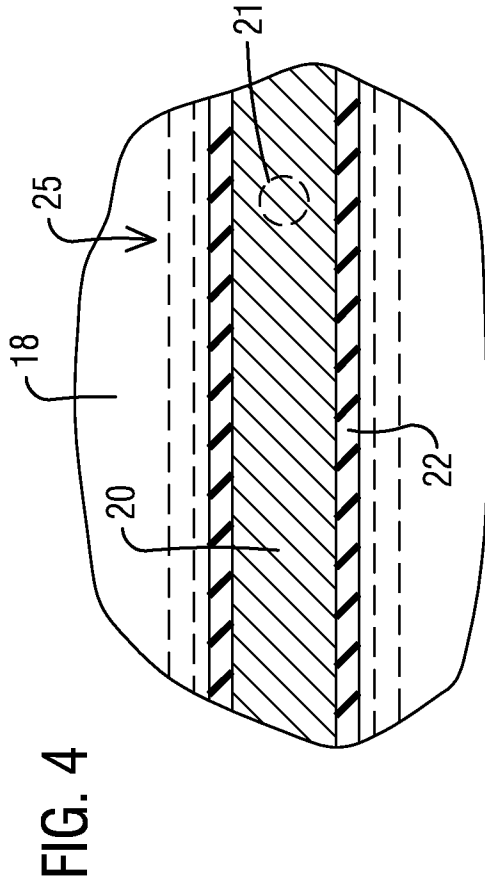
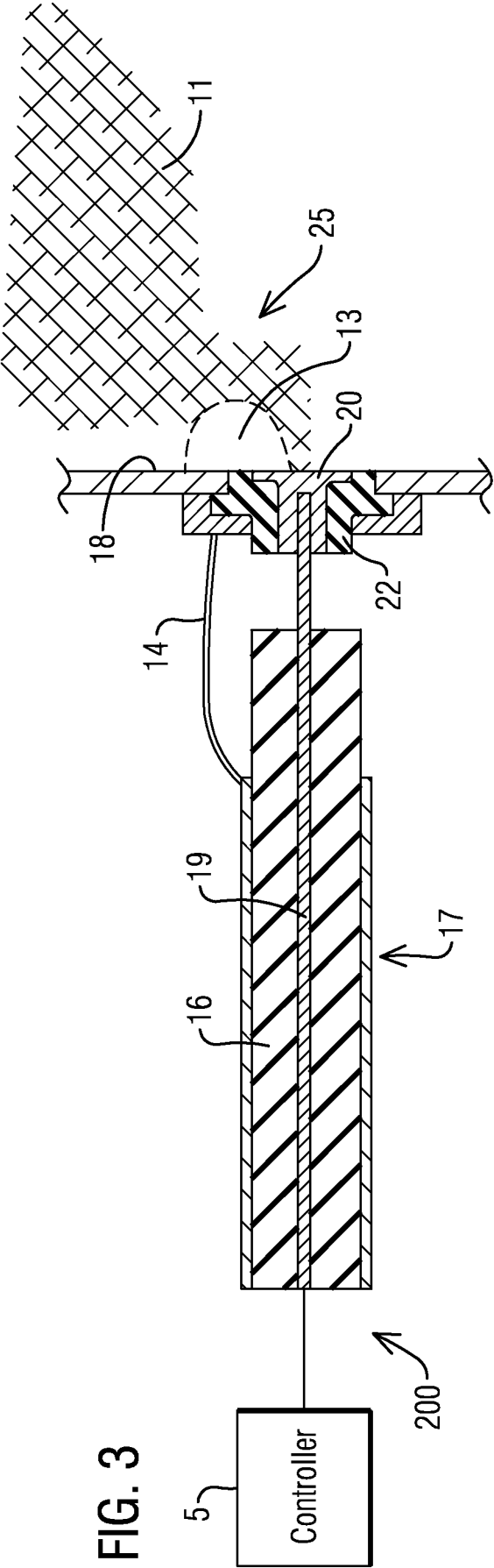


FIG. 5

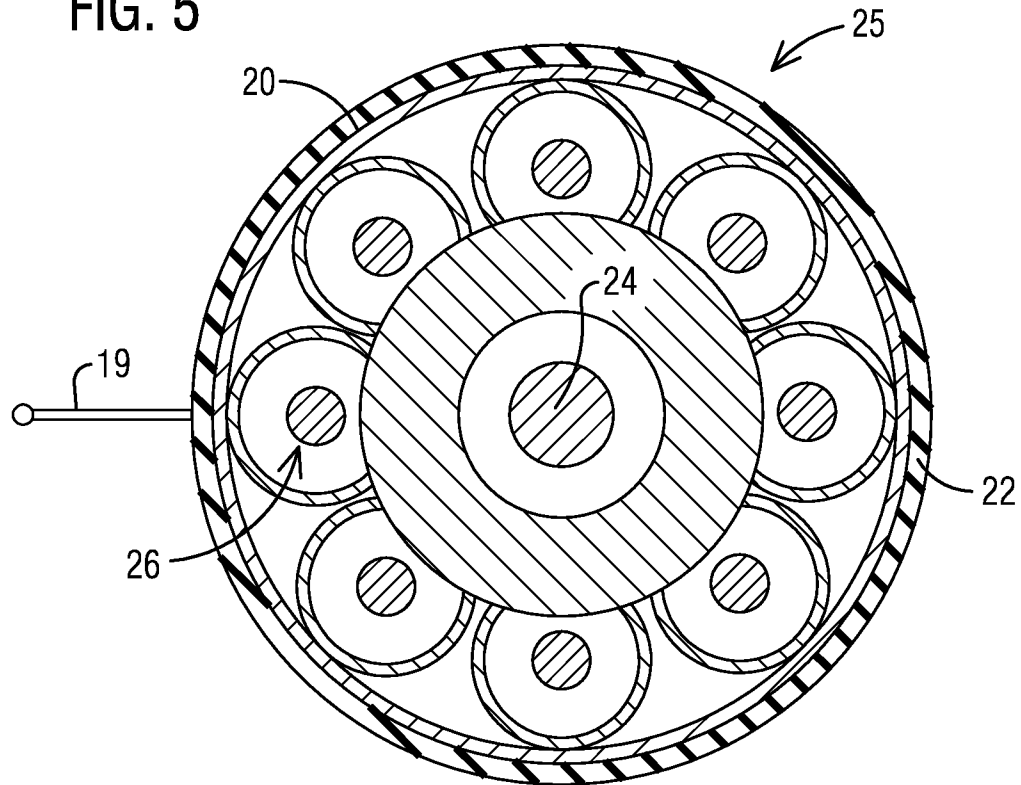


FIG. 6

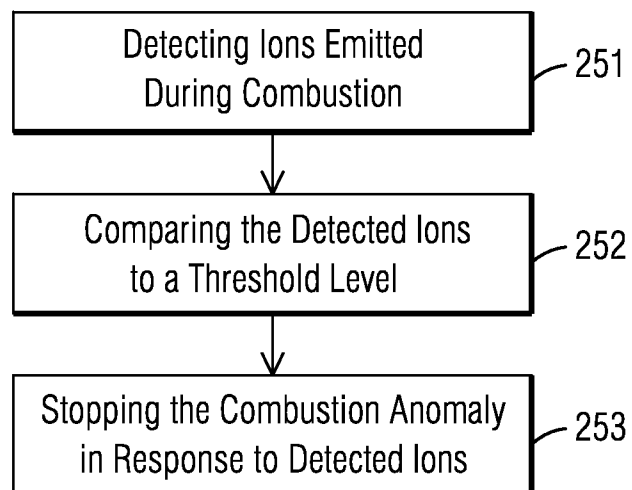


FIG. 7

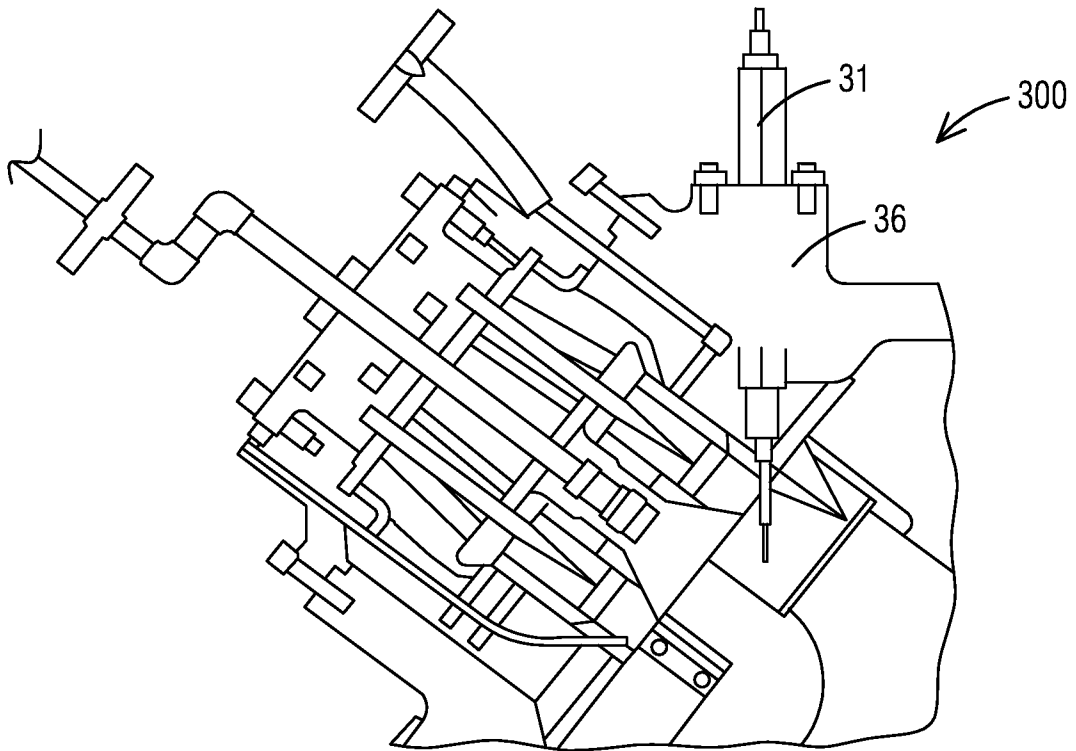


FIG. 8

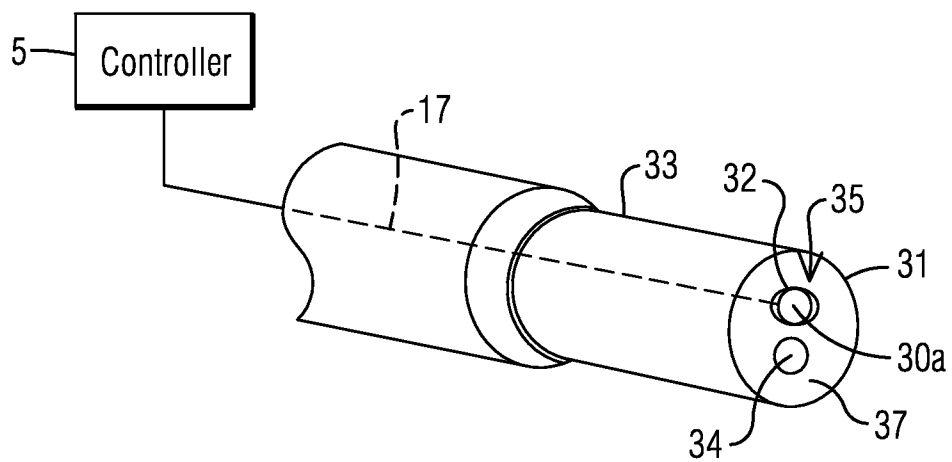


FIG. 9

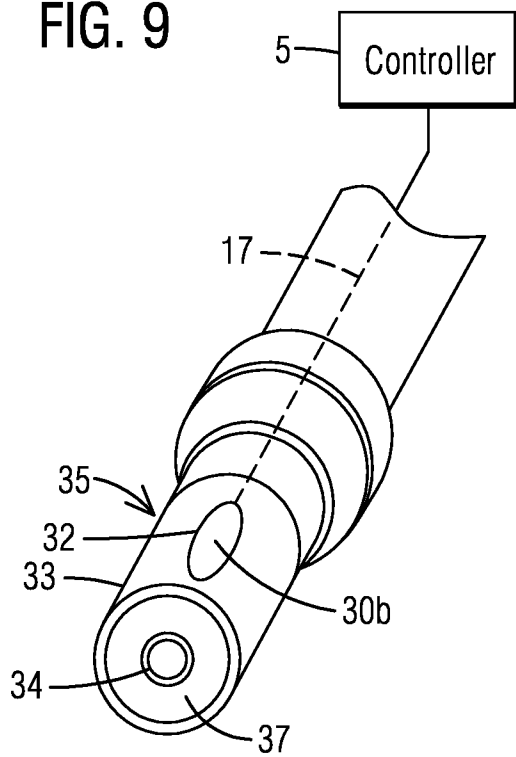


FIG. 10

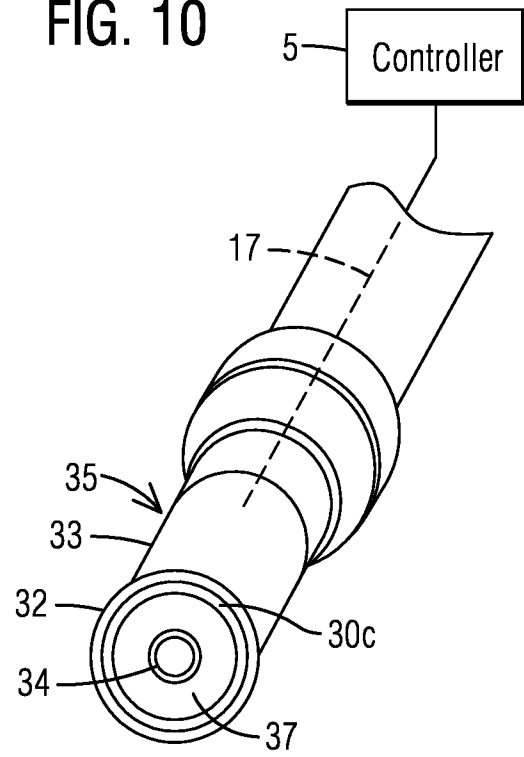


FIG. 11A

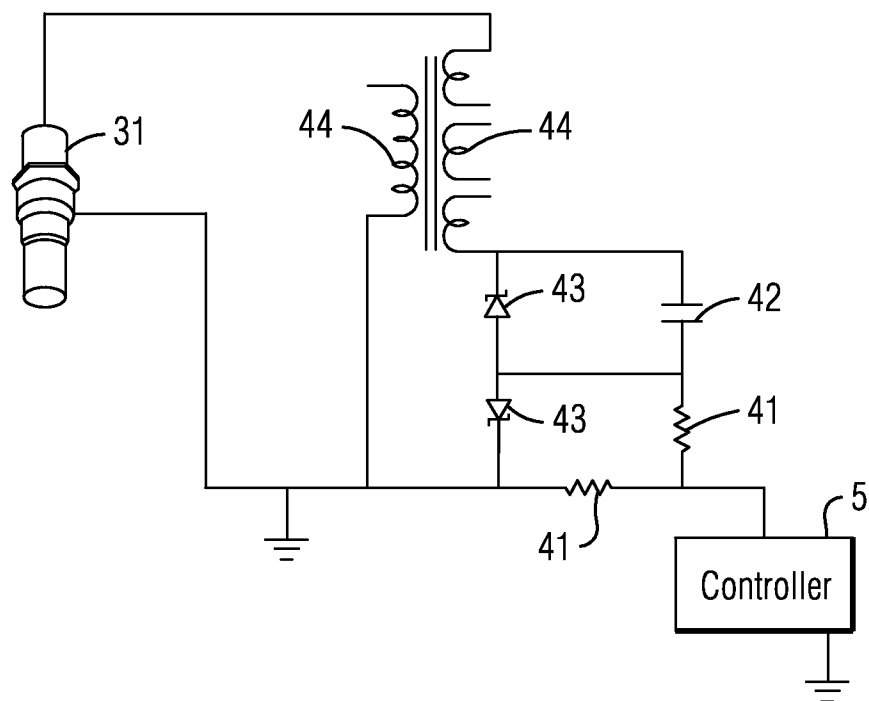


FIG. 11B

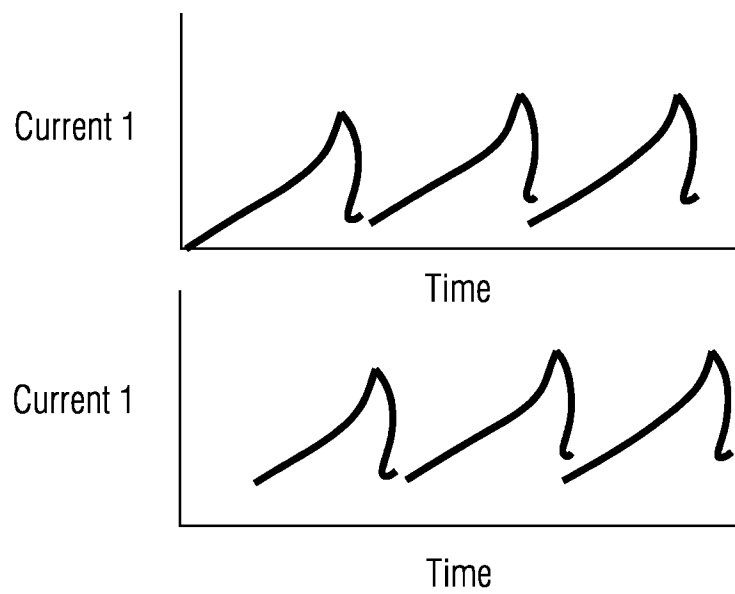
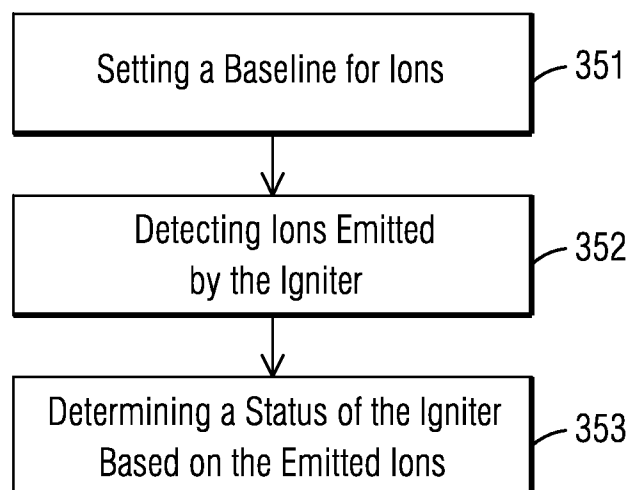


FIG. 12



INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/038222

A. CLASSIFICATION OF SUBJECT MATTER
INV. F23R3/00 F23N5/12
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)
F23R F23N

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/123653 A1 (BENSON KELLY J [US]) 1 July 2004 (2004-07-01) paragraphs [0005], [0008] - paragraph [0010] paragraphs [0027], [0028], [0031], [0032], [0035], [0036]; figures 1, 2, 4 -----	1,4,5,7, 9,10
X	EP 2 600 130 A2 (ROLLS ROYCE DEUTSCHLAND [DE]) 5 June 2013 (2013-06-05) -----	1-3,5,7, 9-11, 14-20 6
Y	paragraphs [0004], [0006], [0007], [0011], [0036], [0037] - paragraph [0040]; figures 2, 3 -----	6
Y	US 2007/020567 A1 (BRANSTON DAVID W [DE] ET AL) 25 January 2007 (2007-01-25) paragraphs [0022], [0029] ----- -/-	6



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

18 February 2016

Date of mailing of the international search report

24/05/2016

Name and mailing address of the ISA/

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Authorized officer

Harder, Sebastian

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2015/038222

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2004/123652 A1 (BENSON KELLY J [US] ET AL) 1 July 2004 (2004-07-01)	1,3,7,8,14
A	paragraph [0024] - paragraphs [0028], [0030]; figures 1-6	2
A	----- EP 2 372 242 A1 (GEN ELECTRIC [US]) 5 October 2011 (2011-10-05) paragraphs [0002], [0022]; figures 1-6 -----	1,5,8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/038222

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-11, 14-20

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-11, 14-20

A sensor system comprising an ion sensor and a method for detecting combustion anomalies.

2. claims: 12, 13

A method for detecting a status of the igniter.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2015/038222

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