(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 4 361 292 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
01.05.2024 Bulletin 2024/18

(21) Application number: **23200065.3**

(22) Date of filing: **27.09.2023**

(51) International Patent Classification (IPC):
C21C 5/52 *(2006.01)* ***F27D 21/02*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F27D 21/02; C21C 5/4673; C21C 5/5211;
C21C 2005/5288; C21C 2300/06

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

(30) Priority: **25.10.2022 NL 2033395**

(71) Applicants:
- **Greyling, Frederik Petrus**
  Middelburg
  1050 Mpumalanga (ZA)
- **Greyling, Ruan**
  Mpumalanga 1050 (ZA)

(72) Inventors:
- **Greyling, Frederik Petrus**
  Middelburg
  1050 Mpumalanga (ZA)
- **Greyling, Ruan**
  Mpumalanga 1050 (ZA)

(74) Representative: **Titmus, Craig Edward et al**
Mathys & Squire
The Shard
32 London Bridge Street
London SE1 9SG (GB)

(54) FURNACE WITH STRAY-ARC PROTECTION SYSTEM AND METHOD OF MONITORING FOR STRAY-ARCS EXTERNALLY OF A SHELL OF A FURNACE

(57) A furnace 12 comprises a protection system 10 against stray arcs in predetermined zones 44, 46 externally of a shell of the furnace. The system comprises an electromagnetic signal imaging device 50 mounted and configured to generate data relating to electromagnetic emissions in the predetermined zones. A controller 52 comprising a processor 54 executing a program is connected to the imaging device 50 to receive the generated data. At least one of the imaging device 50 and the program is configured to mask in data from the zone of interest 46 only, and to mask out or discriminate against data from adjacent regions 48. The processor is configured to: process the generated data into intensity data; compare the intensity data to experimentally or empirically predetermined threshold intensity data which is indicative of a stary-arc forming in the zone; and to generate an output when the intensity data exceeds the threshold intensity data.

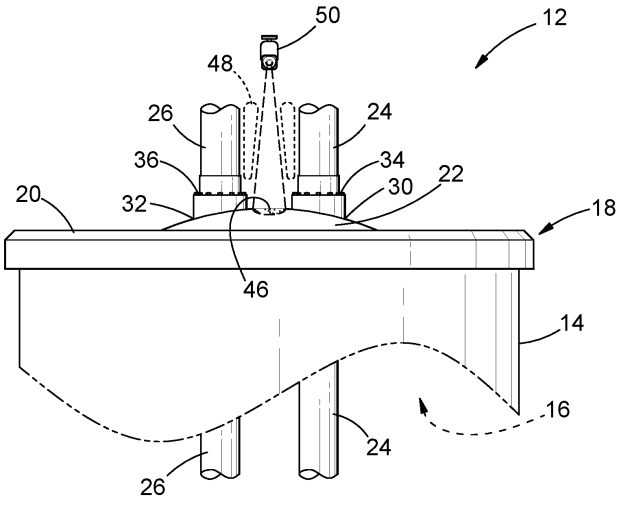

FIGURE 2

Processed by Luminess, 75001 PARIS (FR)

Description

INTRODUCTION AND BACKGROUND

[0001] This invention relates to electric arc furnaces and more particularly to a furnace comprising a stray arc protection system and a method of monitoring for potential stray-arcs externally a shell of the furnace.

[0002] A stray-arc is an arc that typically starts off as a small leakage current that can develop into a small arc that then rapidly develops into a full-blown arc with extremely high energy that can cause substantial damage, destroy equipment and start fires.

[0003] JP20041566865A discloses a system and method for controlling operation of a plasma arc type melting furnace comprising a single elongate electrode extending through the roof of the furnace into a chamber defined by a shell of the furnace and a furnace bottom electrode. In these furnaces, a plasma arc is generated between the elongate electrode and a burden, which is at the same voltage as the furnace bottom electrode, to melt the burden. Stray-arcs may result in various unpredictable places on the interior of the shell. The system of JP20041566865A comprises a current measuring device in series with the electrodes and an infrared camera mounted outside the furnace shell or vessel and which, through a window in the shell, monitors the plasma arc region of the shell. From current data derived from the current measurement device and data relating to the condition (such as shape and temperature) of the plasma arc, the absence or presence of a stray-arc inside the shell whose route or position is unknown, is determined.

[0004] A problem with furnaces comprising at least two elongate electrodes extending from suspension structures above the furnace roof through the roof and into a chamber defined by the furnace shell is that dust and other debris may accumulate on the roof and may result in a stray-arc between the electrodes on the outside of the shell. This stray-arc would not be detectable by the device or system of JP20041566865A and this arc may result in severe damage to the furnace as stated above, resulting in extended production down-time. The same may happen in other zones of interest on the outside of the shell, for example between bus bars connected to the electrodes. On the other hand, background light and/or flames escaping upwardly through electrode seals between the electrode and the roof to beyond a top surface of the roof, are not considered a serious problem in the present context and need to be distinguished from potential stray-arcs on the outside of the shell which are undesirable.

OBJECT OF THE INVENTION

[0005] Accordingly, it is an object of the present invention to provide a furnace comprising a stray arc protection system and method of monitoring for potential stray-arcs externally of a shell of the furnace with which the applicant believes the aforementioned disadvantages may at least be alleviated or which may provide a useful alternative for the known furnaces and methods.

SUMMARY OF THE INVENTION

[0006] According to the invention there is provided a furnace comprising:

- a furnace shell defining a chamber on the inside of the shell;
- a roof; and
- at least a first elongate electrode and a second elongate electrode extending through openings in the roof into the chamber, the electrodes being connected to a furnace power supply via an electric circuit comprising a circuit breaker; and
- a stray arc protection system comprising:
    - ◦ an electromagnetic signal imaging device mounted externally of the shell, the imaging device being mounted and configured to generate data relating to electromagnetic emissions in a predetermined zone of interest externally of the shell and where a stray-arc may develop;
    - ◦ a controller comprising a processor executing an application specific program and which controller is connected to the imaging device to receive the generated data;
    - ◦ at least one of the imaging device and the software being configured to mask in data relating to the zone of interest and to mask out data relating to adjacent regions which are not of interest;
    - ◦ the processor being configured to: process the generated data into intensity data; compare the intensity data to predetermined threshold intensity data which is indicative of a stray-arc forming; and to generate at an output an output signal when the intensity data exceeds the threshold intensity data.

[0007] The term "mask in" is used to indicate that data relating to the zone of interest is processed and the term "masked out" is used to indicate that data relating to adjacent regions which are not if interest, is ignored or discarded.

[0008] The imaging device may be sensitive to visible light and the intensity data may be brightness data of the visible light.

[0009] The imaging device may have a spectral range of 350nm to 1050nm.

[0010] The threshold intensity data may be determined empirically or experimentally for the zone of interest, typically during commissioning of the furnace.

[0011] The zone of interest may be one of a) a zone between the first and second electrodes externally the shell and above the roof and b) a zone between bus bars

extending from the power supply to the electrodes.

[0012] The output may be connected to the circuit breaker to interrupt the electrical circuit and/or to energize an alarm. The alarm may be any one or both of a visible and an audible alarm.

[0013] The invention also includes within its scope a method of monitoring for potential stray-arcs externally of a shell of a furnace, the furnace comprising the shell defining a chamber on the inside of the shell, a roof and at least a first elongate electrode and a second elongate electrode extending through openings in the roof into the chamber, the method comprising the steps of:

- defining at least one zone of interest externally the shell where a stray-arc may develop;
- utilizing an imaging device to capture data relating to electromagnetic emissions in the zone;
- masking in data relating to the zone of interest and masking out data relating to adjacent regions which are not of interest;
- processing the generated data into intensity data;
- comparing the intensity data to threshold intensity data which is indicative of a potential stray-arc developing in the zone of interest; and
- in the event of the intensity data exceeding the threshold intensity data, taking preventative measures.

[0014] The imaging device may be sensitive to visible light and the intensity data may be brightness data of the visible light.

[0015] The preventative measures may be any one or both of switching off power to the electrodes and energizing an alarm.

BRIEF DESCRIPTION OF THE ACCOMPANYING DIAGRAMS

[0016] The invention will now further be described, by way of example only, with reference to the accompanying diagrams wherein:

figure 1 is a block diagram of a stray-arc protection system for a furnace;

figure 2 is a diagrammatic side view of a top part of the furnace comprising at least first and second elongate electrodes;

figure 3 is a diagrammatic plan view of the furnace in figure 2;

figure 4 is a diagrammatic view of a furnace power supply connected by bus bars to the electrodes;

figure 5 is a diagram of an example embodiment of a typical display of a user interface of the monitoring system; and

figure 6 is a flow diagram of an example method of monitoring for potential stray-arcs externally of a furnace.

DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

[0017] A stray-arc protection system 10 for a furnace 12 is shown in figure 1 and will be described further below.

[0018] The furnace 12 is shown in figures 2 to 4. The furnace 12 comprises a furnace shell 14 defining a chamber 16 on the inside of the shell and a roof 18. The roof typically comprises a water-cooled outer section 20 circumscribing an electrically non-conducting refractory centre region 22. At least a first elongate electrode 24 and a second elongate electrode 26 extend from a suspension and electrical connection structure 28 (shown in figure 4) above the furnace downwardly through respective openings 30, 32 in the centre region 22 of roof 18 into the chamber. Electrode seals 34, 36 are provided between the inner section 22 and the electrodes 24 and 26, respectively. In other embodiments, the entire roof may be water-cooled.

[0019] As best shown in figure 4, the electrodes are suspended from a suspension and connection structure 28. The electrodes 24, 26 are connected to a furnace power supply 38 by an electrical circuit comprising bus bars 40 and 42, respectively and a circuit breaker 60 (shown in figure 6).

[0020] Certain zones externally of the shell 14 are critical from a perspective of development of potential stray arcs, which are undesirable, and which could cause severe damage to the furnace and other equipment in the vicinity of the furnace. Such zones comprise, but are not limited to, a zone 44 (shown in figure 4) between the bus bars 40 and 42 and a zone 46 (shown in figures 2 and 3) on an upper surface of inner section 22 of the roof between the electrodes 24 and 26, where dust and debris may accumulate and contribute to the formation of undesirable stray-arcs. These zones must be distinguished from other known adjacent or nearby regions 48 (shown in figure 2) which are not considered problematic in the present context, for example, where heat and/or flames may from time to time escape, in known manner, upwardly past the electrode seals 34, 36, to beyond the top surface of the inner section 22 of roof 18.

[0021] Referring to figure 1, the monitoring system 10 comprises an electromagnetic signal imaging device 50 mounted externally of the shell 14. The imaging device may be a high-resolution camera having a spectral range of 350nm to 1050nm. The imaging device is mounted and configured to generate data relating to light emitted in the predetermined zone of interest 44 or 46 externally of the shell and where stray-arcs may develop externally of the shell. A controller 52 comprising a processor 54 executing an application specific program is connected to the imaging device 50 to receive the generated data. At least one of the imaging device 50 and the software is configured to focus on or mask in data from the zone of interest 44 or 46 only, and to mask out or discriminate against data from the adjacent regions, such as regions 48. The processor is configured to: process the generat-

ed data into brightness data; compare the brightness data to predetermined threshold brightness data which is indicative of a stray-arc forming in the zone; and to generate at an output 56 an output signal when the brightness data reaches the threshold brightness data.

[0022] The output 56 is connected in known manner to a plant controller 58 and the plant controller is connected, also in known manner, to control the furnace transformer circuit breaker 60 of power supply 38.

[0023] Referring to figures 1 and 5, for purposes of commissioning or installation, there is provided a computer 62 having a GUI 64 (shown in figure 5) which is connected to the controller 52.

[0024] During installation, a human installer 66 would select and define (as shown at 68 in figure 1), via the computer 64, the zone of interest 44 or 46 to be covered by the imager 50. The installer would also empirically or experimentally determine and set (as shown at 70 in figure 1) the threshold brightness data which would be indicative of a potential stray-arc developing in the zone. The commissioning process allows the selection of the brightness threshold data suitably above ambient light level of the furnace roof area. This ensures reliable detection while accounting for varying light conditions.

[0025] Data relating to these selections is transmitted by the computer 62 to the controller 52.

[0026] In use, the imager 50 continually generates data relating to light generated in the zone of interest. The generated data is fed in real time to the controller 52 and the processor 54, for processing (also in real time) into brightness data as described above. Referring to figure 5, the focus on or masking in of the data relating to zone 46 and discriminating against or masking out data relating to adjacent region 48 may in some embodiments be achieved by the software processing brightness data from pixels in an image generated by the device 50 corresponding to zone 46 as described above, and not those of or ignoring the pixels corresponding to region 48.

[0027] In a case where the brightness data reaches or exceeds the threshold brightness data (shown in broken lines in figure 5), the output signal at output 56 causes the plant controller 58 to transmit a signal to the circuit breaker 60, to interrupt power to the electrodes, thereby to prevent the potential stray-arc from forming or developing further in the zone of interest.

[0028] An associated method of monitoring for potential stray-arcs in at least one zone of interest externally of a furnace shell is shown in figure 6, which is self-explanatory.

[0029] It will be appreciated that the protection system 10 monitors the defined zones of interest 44 or 46 only and masks out adjacent or even immediately adjacent regions 48 where light brightness may from time to time, for known reasons which are not considered dangerous in the current context, rise to elevated levels. This in effect mitigates false triggers from background light sources.

Claims

1. A furnace comprising:

- a furnace shell defining a chamber on the inside of the shell;
- a roof; and
- at least a first elongate electrode and a second elongate electrode extending through openings in the roof into the chamber, the electrodes being connected to a furnace power supply via an electric circuit comprising a circuit breaker; and
- a stray arc protection system comprising:

    ◦ an electromagnetic signal imaging device mounted externally of the shell, the imaging device being mounted and configured to generate data relating to electromagnetic emissions in a predetermined zone of interest externally of the shell and where a stray-arc may develop;

    ◦ a controller comprising a processor executing an application specific program and which controller is connected to the imaging device to receive the generated data;

    ◦ at least one of the imaging device and the software being configured to mask in data relating to the zone of interest and to mask out data relating to adjacent regions which are not of interest;

    ◦ the processor being configured to: process the generated data into intensity data; compare the intensity data to predetermined threshold intensity data which is indicative of a stray-arc forming; and to generate at an output an output signal when the intensity data exceeds the threshold intensity data.

2. The furnace as claimed in claim 1 wherein the imaging device is sensitive to visible light and the intensity data is brightness data of the visible light.

3. The furnace as claimed in any one of claim 1 and claim 2 wherein the imaging device has a spectral range of 350nm to 1050nm.

4. The furnace as claimed in any one of the preceding claims wherein the threshold intensity data is determined empirically or experimentally for the zone of interest.

5. The furnace as claimed in any one of the preceding claims wherein the zone of interest comprises one of a) a zone between the first and second electrodes externally the shell and above the roof and b) a zone between bus bars extending from the power supply to the electrodes.

6. The furnace as claimed in any one of the preceding claims wherein the output is connected to the circuit breaker to interrupt the electrical circuit and/or to energize an alarm.

7. A method of monitoring for potential stray-arcs externally of a shell of a furnace, the furnace comprising the shell defining a chamber on the inside of the shell, a roof and at least a first elongate electrode and a second elongate electrode extending through openings in the roof into the chamber, the method comprising the steps of:

- defining at least one zone of interest externally the shell where a stray-arc may develop;
- utilizing an imaging device to capture data relating to electromagnetic emissions in the zone;
- masking in data relating to the zone of interest and masking out data relating to adjacent regions which are not of interest;
- processing the generated data into intensity data;
- comparing the intensity data to threshold intensity data which is indicative of a potential stray-arc developing in the zone of interest; and
- in the event of the intensity data exceeding the threshold intensity data, taking preventative measures.

8. The method of claim 7 wherein the imaging device is sensitive to visible light and the intensity data is brightness data of the visible light.

9. The method of any one of claim 7 and claim 8 wherein the preventative measures comprise any one or both of switching off power to the electrodes and energizing an alarm.

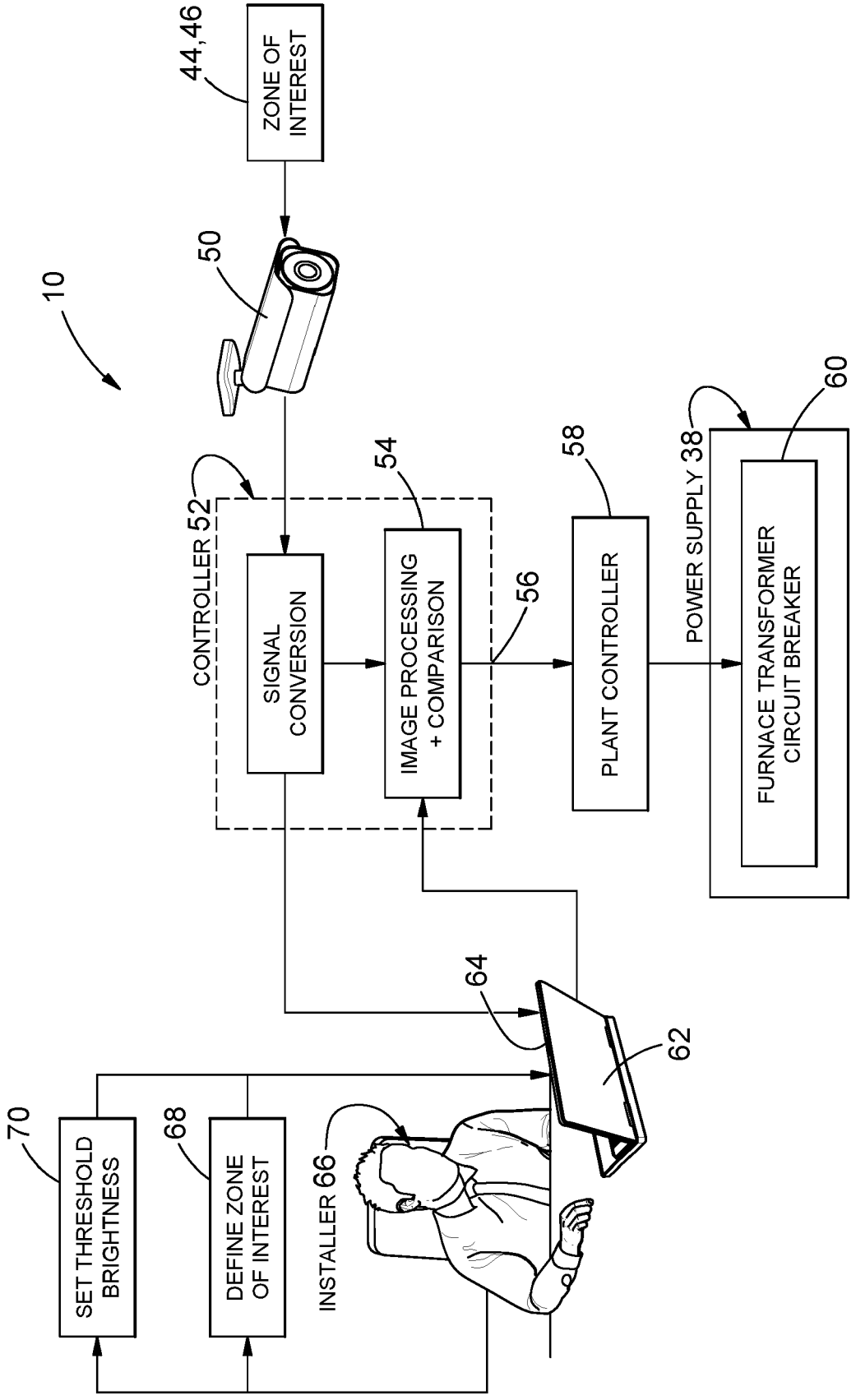
10
44,46
ZONE OF INTEREST
50
CONTROLLER 52
SIGNAL CONVERSION
54
IMAGE PROCESSING + COMPARISON
56
58
PLANT CONTROLLER
POWER SUPPLY 38
60
FURNACE TRANSFORMER CIRCUIT BREAKER
64
62
70
SET THRESHOLD BRIGHTNESS
68
DEFINE ZONE OF INTEREST
INSTALLER 66

FIGURE 1

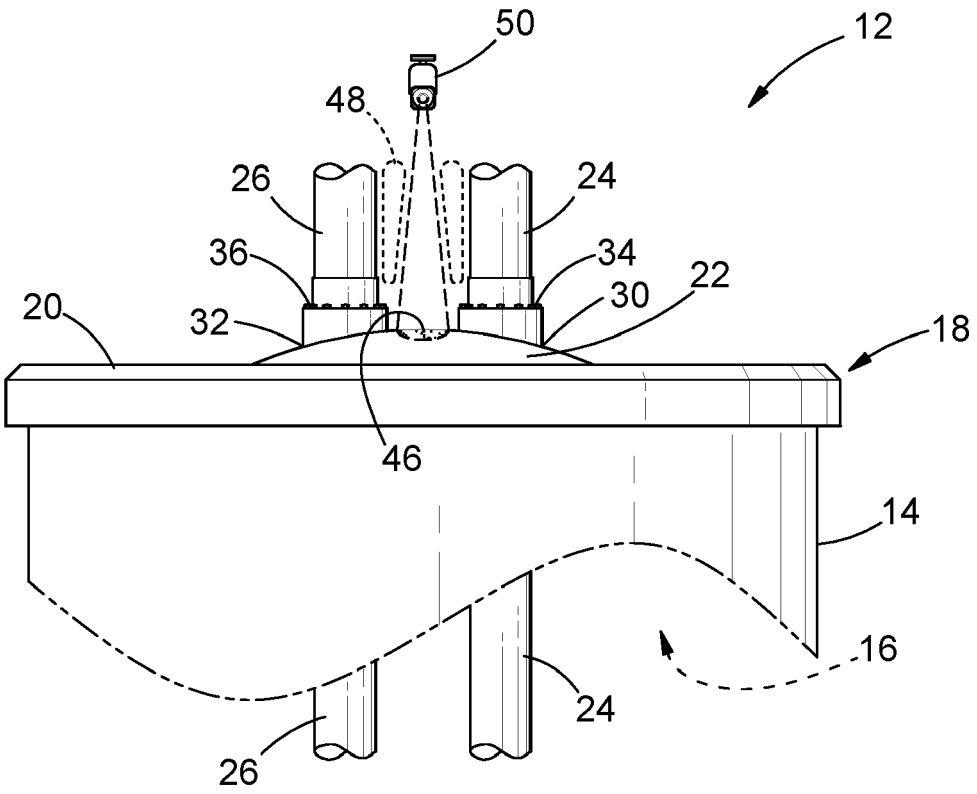

FIGURE 2

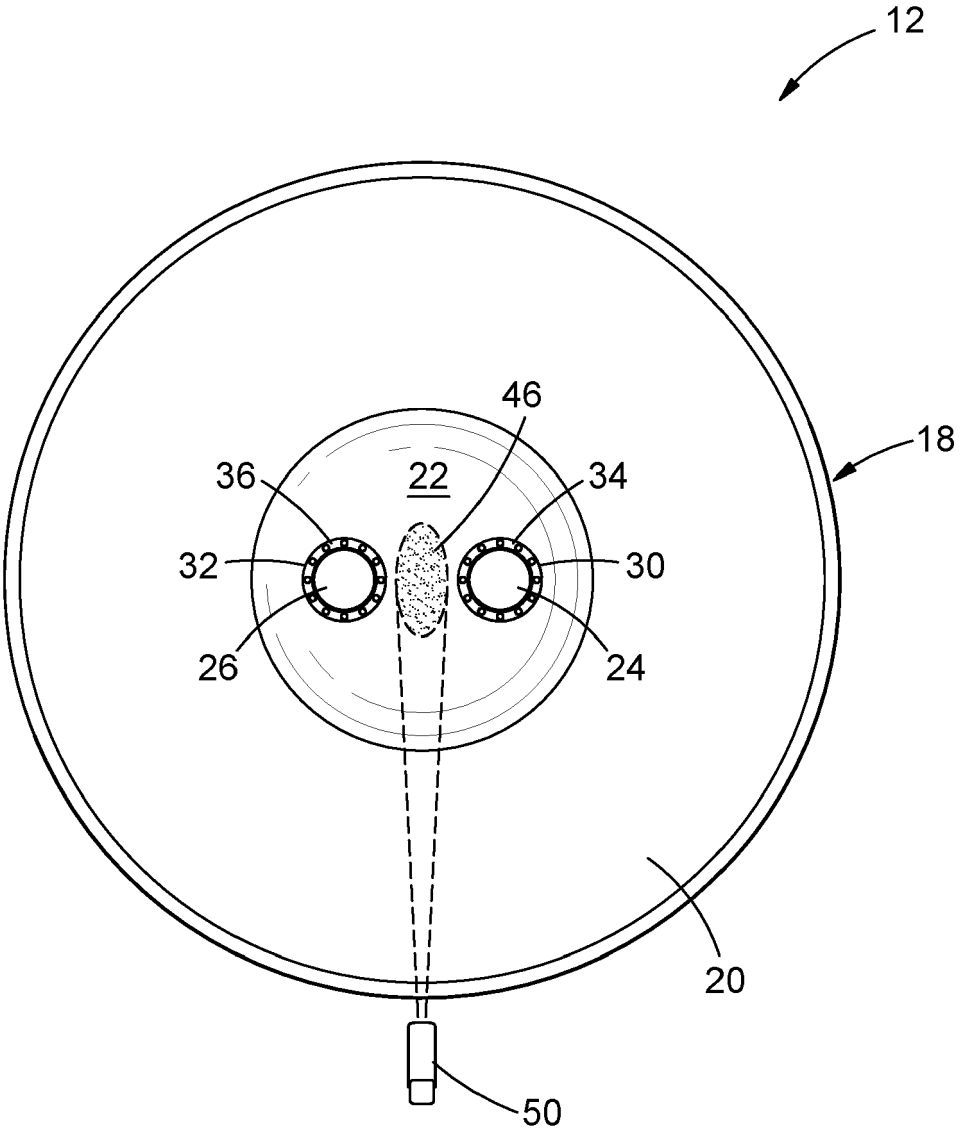

FIGURE 3

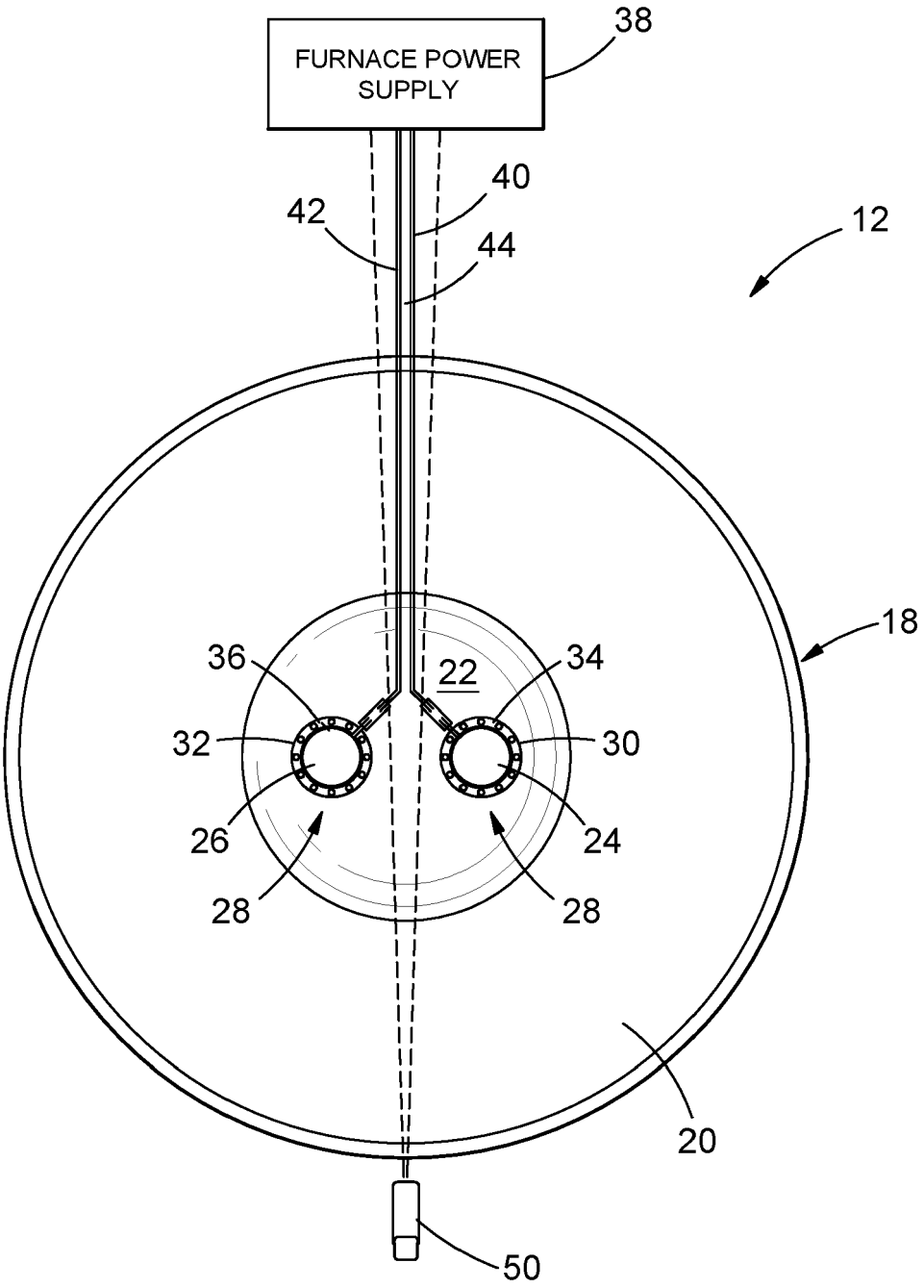
FURNACE POWER SUPPLY
38
40
42
44
12
18
36
22
34
32
30
26
24
28
28
20
50

FIGURE 4

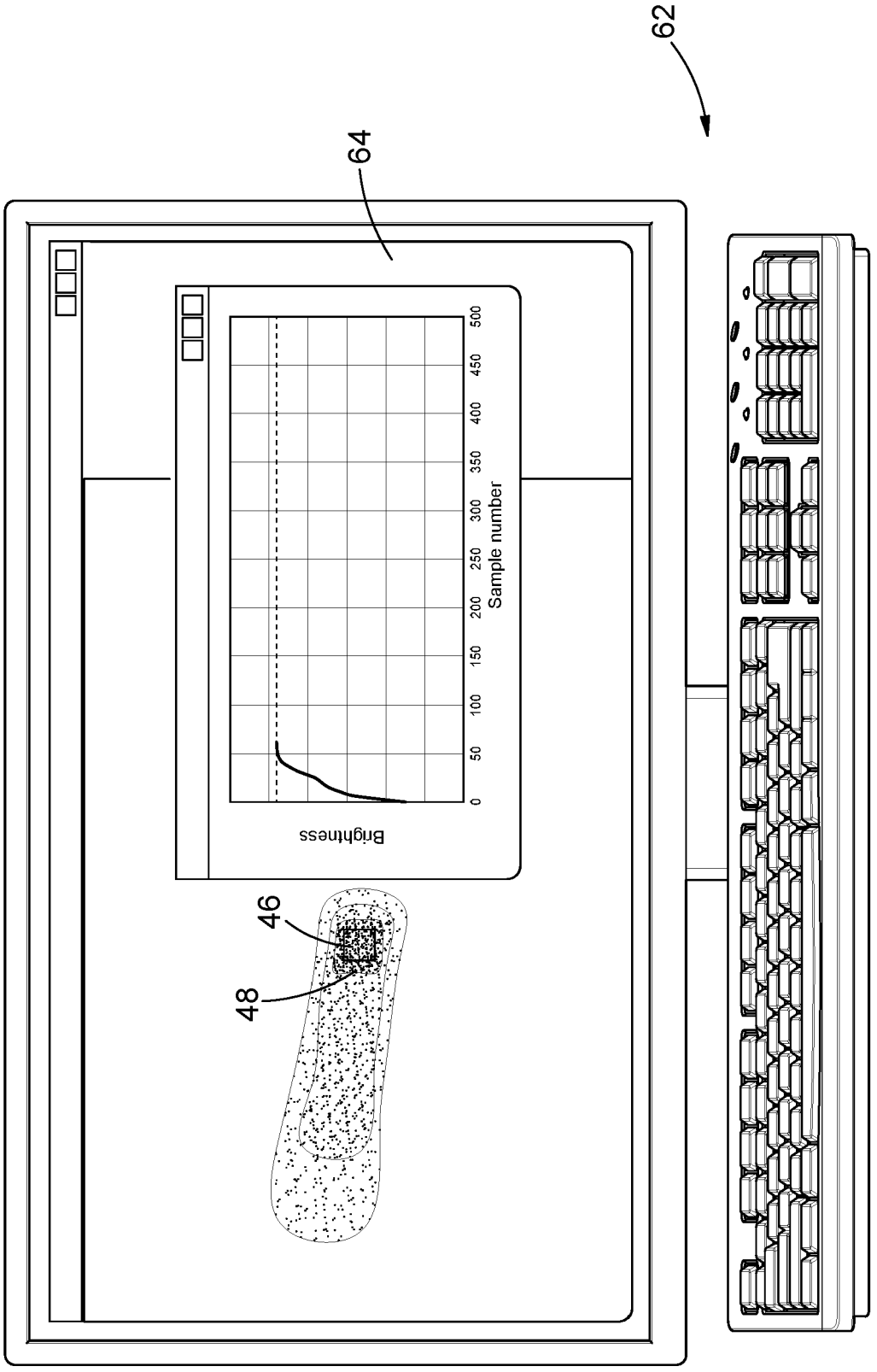
62
64
Brightness
Sample number
0
50
100
150
200
250
300
350
400
450
500
46
48

FIGURE 5

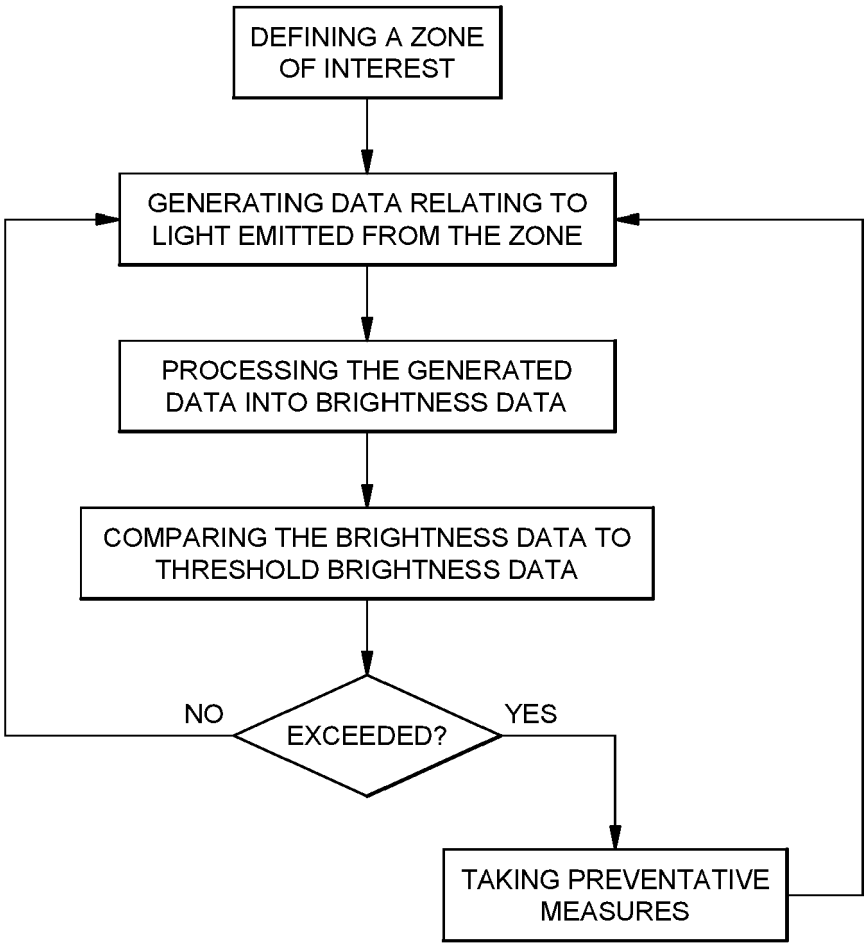
DEFINING A ZONE OF INTEREST
GENERATING DATA RELATING TO LIGHT EMITTED FROM THE ZONE
PROCESSING THE GENERATED DATA INTO BRIGHTNESS DATA
COMPARING THE BRIGHTNESS DATA TO THRESHOLD BRIGHTNESS DATA
EXCEEDED?
NO
YES
TAKING PREVENTATIVE MEASURES

FIGURE 6

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 20 0065

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP 2004 156865 A (MITSUBISHI HEAVY IND LTD) 3 June 2004 (2004-06-03) * Machine translation; paragraph [0008] - paragraph [0019]; claims 1-3; figure 1 *	1-9	INV. C21C5/52 F27D21/02
A	ZA 98 481 B (PYROMET PROPRIETARY LIMITED) 30 July 1998 (1998-07-30) * paragraph [Backgroundoftheinvention] * * paragraph [Descriptionofanembodiment] *	1-9	
A	EP 3 968 120 A1 (AIR LIQUIDE [FR]) 16 March 2022 (2022-03-16) * paragraph [0004] - paragraph [0007] * * paragraph [0015] - paragraph [0022] * * figures 1,2 *	1-9	
A	US 2019/322562 A1 (TURNER SUSAN FIONA [GB] ET AL) 24 October 2019 (2019-10-24) * paragraph [0011] - paragraph [0016] * * paragraph [0038] - paragraph [0048] *	1-9	

TECHNICAL FIELDS SEARCHED (IPC)
C21C F27D C21B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 February 2024	Desvignes, Rémi

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 23 20 0065

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

08-02-2024

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2004156865 A	03-06-2004	NONE	
ZA 98481 B	30-07-1998	NONE	
EP 3968120 A1	16-03-2022	BR 112023003970 A2	18-04-2023
		CN 115997096 A	21-04-2023
		EP 3968120 A1	16-03-2022
		EP 4211530 A1	19-07-2023
		JP 2023541859 A	04-10-2023
		US 2023358475 A1	09-11-2023
		WO 2022053390 A1	17-03-2022
US 2019322562 A1	24-10-2019	BR 112019011029 A2	08-10-2019
		EP 3551588 A1	16-10-2019
		JP 7106537 B2	26-07-2022
		JP 2020513529 A	14-05-2020
		US 2019322562 A1	24-10-2019
		WO 2018104695 A1	14-06-2018

EPO FORM P0459

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

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

- JP 20041566865 A **[0003] [0004]**