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(54) **METHOD AND APPARATUS TO CALIBRATE A VALVE OF A GAS BOILER**

(57) Method to calibrate a valve of a gas boiler, the valve (2) having at least one movable calibration element (2a, 2b) in which boiler operating parameters are measured by means of measuring instruments (5), at least one 3D image of the valve (2) is acquired through an optical acquisition means (12), orientation and position of the calibration element (2a, 2b) are identified from the 3D image, a motor-driven tool (13a, 13b), which is couplable to the calibration element (2a, 2b), is moved through an anthropomorphic robot (8) along a path ending with the coupling between the tool (13a, 13b) and the calibration element (2a, 2b) and calculated based on position and orientation of the calibration element (2a, 2b), and the tool (13a, 13b) is operated to adjust the calibration element (2a, 2b) based on the measured parameter so as to carry out an adjustment cycle of the calibration element (2a, 2b).

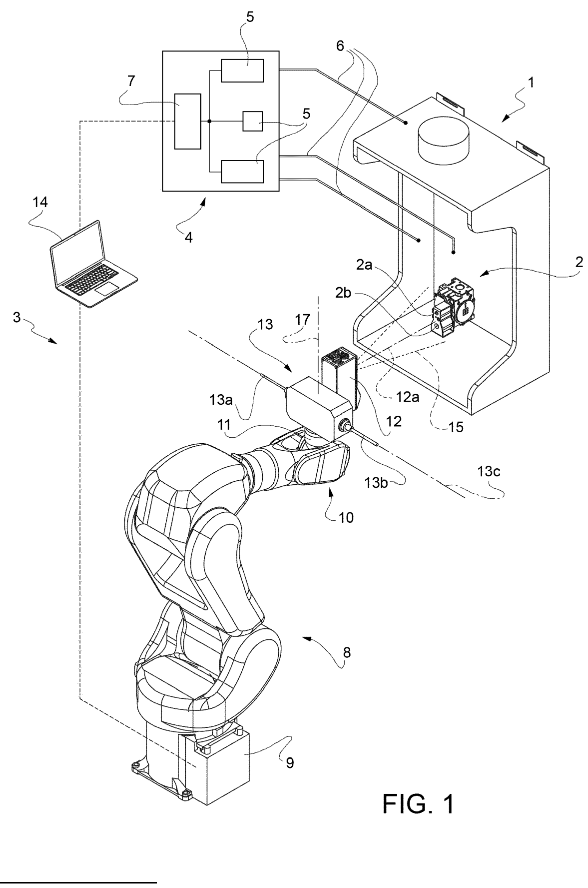

FIG. 1

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Description

PRIORITY CLAIM

[0001] This application claims priority from European Patent Application No. 17160931.6 filed on March 14, 2017 and Italian Patent Application No. 102017000108941 filed on September 28, 2017.

[0002] The present invention relates to a method to calibrate a valve of a gas boiler and to a corresponding calibration apparatus.

[0003] In particular, the present invention finds advantageous, but not exclusive, application in the calibration of methane gas boilers in a boiler production line, to which the following description will make explicit reference without thereby losing in generality.

[0004] A production line of gas boilers includes, usually at the end of the line, a testing station, in which each boiler is connected to a plurality of measuring instruments for measuring a series of boiler operating parameters that are used for the calibration of some parts of the boiler. The instruments allow measuring gas flow rate, water flow rate, gas and water pressure at various points of the relevant circuits inside the boiler, ambient temperature, water temperature, gas temperature and concentration of various gases at the fumes exhaust.

[0005] One of the most important boiler components to be calibrated is the so-called gas valve, i.e. the valve that regulates the flow rate of the gas supplied to the boiler burner, and therefore regulates the boiler power. The valve includes a pair of adjustment screws, a so-called "minimum" screw to adjust the minimum gas flow rate and therefore the minimum boiler power, and a so-called "maximum" screw to adjust the maximum gas flow rate and therefore the maximum boiler power, that allow calibrating the valve based on some measured parameters. The parameters to be measured for a correct calibration of the gas valve depend on the type of gas boiler. In the case of a conventional boiler, the gas pressure is measured at a point in the gas circuit inside the boiler. On the other hand, in the case of a condensation type boiler, it is measured the percentage content of carbon dioxide in the fumes returned to dry fumes conditions, namely once eliminated the moisture that is inevitably created by combustion.

[0006] Typically, the adjustment of the gas valve screws is done manually by an operator by means of a screwdriver, based on the parameters that the operator visually reads on the measuring instruments, following a predetermined adjustment cycle. The testing station is substantially a measuring bench comprising measuring instruments, which are read by the operator to obtain the necessary parameters for adjusting the minimum and maximum screws. It is clear that the manual calibration of the gas valves slows down the production line and frequently causes human errors.

[0007] The object of the present invention is to provide a method to calibrate a valve of a gas boiler, which is free from the aforesaid drawbacks and, at the same time, is easy and inexpensive to manufacture.

[0008] In accordance with the present invention, it is provided a method and an apparatus to calibrate a valve of a gas boiler as defined in the attached claims.

[0009] The present invention will now be described with reference to the accompanying drawings showing a non-limiting embodiment, in which:

- Figure 1 shows the apparatus to calibrate a valve of a gas boiler in a first step of the method of the present invention; and
- Figure 2 shows the apparatus of Figure 1 in a subsequent step of the method of the invention.

[0010] In Figure 1, the reference number 1 generally indicates as a whole a methane gas boiler comprising a valve 2 for adjusting the gas flow supplied to the burner (not shown) of the boiler 1 and the reference number 3 indicates a calibration apparatus to calibrate the valve 2. The valve 2 comprises two calibration elements 2a and 2b consisting e.g. of two adjustment screws for adjusting the minimum and maximum values of the gas flow supplied to the burner (not shown) of the boiler 1.

[0011] The calibration apparatus 3 comprises a measuring bench 4, which in turn comprises a plurality of measuring instruments 5 of known type connected in a known manner to a plurality of control points of the boiler 1 by means of flexible pipes 6 to measure various operating parameters of the boiler 1, such as e.g. pressure, flow rate, temperature and/or concentration of gaseous substances in the control points. In particular, the measured operating parameters include the pressure of the gas circuit of the boiler 1 and the carbon dioxide concentration in the exhaust fumes. The measuring bench 4 comprises a processing and controlling unit 7, typically constituted by a personal computer and interfaced with the measuring instruments 5 to acquire the measured values of the operating parameters.

[0012] According to the present invention, the calibration apparatus 3 comprises an anthropomorphic robot 8 arranged in front of the boiler 1 and provided with its own control unit 9, which controls the movement of the motor-driven joints of the anthropomorphic robot 8. The anthropomorphic robot 8 comprises a movable wrist 10 and a support 11 mounted on the wrist 10. The calibration apparatus 3 comprises optical acquisition means 12 fixed on the support 11 for acquiring images or profiles of the valve 2 and a motor-driven tool assembly 13, also fixed on the support 11, to adjust the calibration elements 2a and 2b of the valve 2. The control unit 9 also controls the operation of the tool assembly 13.

[0013] The tool assembly 13 comprises two motor-driven tools 13a and 13b, rotating with respect to relative rotation axes, and in particular two respective motor-driven screwdrivers oriented in the opposite sense along a same direction 13c. In Figure 1, the rotation axes of the tools 13a and 13b coincide with the direction 13c. The tool 13a is used for the calibration element 2a and the other tool 13b is used for the calibration element 2b. The tool assembly 13 is mounted on the support 11 with the direction 13c that is transverse, preferably orthogonal, to the optical axis 12a of the optical acquisition means 12.

[0014] The calibration apparatus 3 comprises a further processing and controlling unit 14, typically constituted by a personal computer, which interfaces with the optical acquisition means 12 to receive the images or profiles of the valve 2, with the processing and controlling unit 7 of the measurement bench 4 to obtain measured values of the operating parameters and with the control unit 9 to control the anthropomorphic robot 8, thus correctly placing the optical acquisition means 12 and the tool assembly 13 in front of the valve 2 and operating the tool assembly to adjust the calibration elements 2a and 2b. Basically, the processing and controlling unit 14 coordinates the calibration operations of the valve 2.

[0015] In particular, the processing and controlling unit 14 is configured to process the images or profiles acquired through the optical acquisition means 12 so as to obtain a three-dimensional image, briefly called 3D image hereinafter, of the valve 2, to identify the position and orientation of the calibration elements 2a and 2b from the 3D image with respect to a reference system integral with the anthropomorphic robot 8, to calculate, based on position and orientation of the calibration elements 2a and 2b, an approaching path of the tool assembly 13 to the calibration elements 2a and 2b, which ends with a correct coupling between each tool 13a, 13b and the respective calibration element 2a, 2b, and to control the anthropomorphic robot 8 for moving the tool assembly 13 along the approaching path and for operating the tools 13a and 13b to adjust the calibration elements 2a and 2b based on the measured values of the operating parameters in order to carry out the desired adjustment cycle. In more detail, as regards the control of the anthropomorphic robot 8, the processing and controlling unit 14 is configured through programming primitives provided by the control unit 9. Therefore, the measured values of the operating parameters are used as feedback values to adjust the minimum and maximum values of the gas supply flow rate, i.e. to suitably adjust the rotation of the calibration elements 2a and 2b.

[0016] Still referring to Figure 1, the optical acquisition means 12 consist of a laser scanner or profilometer emitting a planar, e.g. horizontal, light beam 15, on the valve 2 to acquire a corresponding two-dimensional profile of the valve 2 along a plane defined by the light beam 15.

[0017] The valve calibration method 2 implemented by the calibration apparatus 3 is described in greater detail hereinafter.

[0018] In a first step of the valve calibration method 2, the processing and controlling unit 14 controls the anthropomorphic robot 8, thus moving the laser scanner 12 along a linear acquisition path 16 orthogonal to the light beam 15, i.e. vertical, to acquire a plurality of two-dimensional profiles of the valve 2, which are equidistant along the acquisition path 16. The processing and controlling unit 14 processes the plurality of two-dimensional profiles to obtain a 3D image in the form of a cloud of points.

[0019] According to a further embodiment of the invention not shown, the optical acquisition means 12 consist of a stereoscopic camera, e.g. a time-of-flight camera or a Range Sensor, for directly acquiring a 3D image. In this case, in the first step of the valve calibration method 2, the processing and controlling unit 14 controls the anthropomorphic robot 8 to hold the stereoscopic camera in a fixed position in front of the valve 2.

[0020] In a subsequent step of the calibration method, the position of the calibration elements 2a and 2b is identified in terms of Cartesian coordinates and the orientation of the calibration elements 2a and 2b is identified in terms of Euler angles. In order to determine the position and orientation of the calibration elements 2a and 2b with respect to the reference system integral with the anthropomorphic robot 8, the processing and controlling unit 14 is configured to run algorithms of known type to identify in the 3D image some reference characteristics of known shape, such as holes, corners and particular curved surfaces of the valve 2, and to obtain the deviations of the reference characteristics with respect to the reference system of the anthropomorphic robot 8. The position and orientation of the calibration elements 2a and 2b are determined based on these deviations.

[0021] As previously stated, the calibration method uses position and orientation of the calibration elements 2a and 2b to determine an approaching path of the tool assembly 13 to the calibration elements 2a and 2b. In particular, the approaching path comprises a first section in which the wrist 10 is generally closer to the valve 2, a second section ending e.g. with the tool 13a coupled to the calibration element 2a, as shown in Figure 2, and a third section ending with the other tool 13b coupled to the other calibration element 2b. The second section comprises a first rotation of the wrist 10 with respect to an axis 17 perpendicular to a plane on which the direction 13c and the optical axis 12a lie, said rotation corresponding to an angle formed between the direction 13c and the optical axis 12a, and the third section comprises a second rotation of the wrist 10, again with respect to the axis 17, having opposite direction to the first rotation and an angle of 180°.

[0022] According to an alternative and not shown embodiment of the present invention, the second section ends with the tool 13b coupled to the calibration element 2b and the third section ends with the other tool 13a coupled to the other calibration element 2a.

[0023] Therefore, the first rotation of the wrist 10 makes a first tool 13a, 13b with its axis of rotation parallel to the axis of a first calibration element 2a, 2b, and the second rotation of the wrist 10 makes the other tool 13b, 13a with its axis of rotation parallel to the axis of the other calibration element 2b, 2a.

[0024] The processing and controlling unit 14 controls the anthropomorphic robot 8 through the control unit 9 to move the tool assembly 13 along the approaching path and to operate the tool assembly 13 to carry out the adjustment cycle of the calibration elements 2a and 2b. Thus, the movement of the tool assembly 13 comprises the two successive rotations of the wrist 10 described above. The two tools 13a and 13b are coupled to respective calibration elements 2a and 2b, one after the other, and consequently operated one after the other according to suitable rules set by the adjustment cycle and programmed in the processing and controlling unit 14. For example, the adjustment cycle may first adjust the minimum value and then the maximum value of the gas flow rate, or vice versa. The processing and controlling unit 14 acts on the adjustment of each calibration element 2a, 2b based on the measured values of the operating parameters received from the processing and controlling unit 7 and based on the set rules of the adjustment cycle.

[0025] The calibration apparatus 3 is conveniently inserted at the end of a boiler production line, and in particular at a final testing station of the production line (not shown). The production line includes its own control unit, which interfaces with the processing and controlling unit 14. The adjustment cycle includes rules for evaluating the outcome of the calibration of the valve 2 based on the measured values of the operating parameters and of the settings applied to calibration elements 2a and 2b. The processing and controlling unit 14 communicates the result of the calibration to the control unit of the production line. If the calibration result is negative, the production line discards the boiler 1.

[0026] According to a further embodiment not shown in the present invention, the apparatus 3 does not comprise the processing and controlling unit 14 and the functions performed by this unit 14 are carried out by the processing and controlling unit 7, also formed by a personal computer. Therefore, the processing and controlling unit 7 interfaces with the optical acquisition means 12 for receiving the images or profiles of the valve 2 and with the control unit 9 for controlling the anthropomorphic robot 8, thus correctly placing the optical acquisition means 12 and the tool assembly 13 in front of the valve 2 and operating the tool assembly to adjust the calibration elements 2a and 2b. In particular, in the absence of the processing and controlling unit 14, the processing and controlling unit 7 is configured and programmed as previously described with reference to the unit 14 to perform the same functional steps of the unit 14. Substantially, according to the aforementioned further embodiment, the processing and controlling unit 7 coordinates the calibration operations of the valve 2. Finally, with the calibration apparatus 3 inserted at the end of said boiler production line, the processing and controlling unit 7 interfaces with the control unit of the boiler production line.

[0027] Although the invention described above makes particular reference to an exemplary embodiment, it is not to be considered limited to this embodiment, since its scope includes all variants, modifications or simplifications covered by the appended claims, in which, for example:

- the tool assembly 13 comprises a single motor-driven tool, which is couplable to both calibration elements 2a and 2b and the processing and controlling unit 14 calculates a different approaching path of the tool assembly 13, which provides for a single rotation of the wrist 10 of the anthropomorphic robot 8 (the aforementioned first rotation) and a linear displacement for moving the tool from one calibration element to another;
- the tools 13a and 13b have their screw coupling ends turned the same part, i.e. with the same orientation along the direction 13c, have the same interaxis of the calibration elements 2a and 2b, which are formed by respective screws, so that the tools 13 can approach the respective calibration elements 2a and 2b and be simultaneously coupled to them, and therefore the approaching path of the tool assembly 13 provides for only one rotation of the wrist 10 of the anthropomorphic robot 8 (the aforesaid first rotation);
- the calibration elements 2a and 2b are constituted by respective screws having any type of head, and the tools 13a and 13b generally have respective axial ends, which is couplable to the heads of the screws: for example, the tools are Allen wrenches or socket wrenches;
- the calibration elements 2a and 2b are different from screws, e.g. they are linear cursors, and consequently the tools 13a and 13b are different from screwdrivers, e.g. they are linearly movable rods, each of which is provided with a respective end that is couplable to the head of a respective cursor;
- the valve 2 has only one calibration element 2a and therefore the tooling assembly 13 has only one motor-driven tool;
- the optical acquisition means 12 are a stereoscopic camera, stationary with respect to the boiler 1 and not carried by the anthropomorphic robot 8; and
- the 3D image consists of NURBS surfaces obtained by processing images or profiles acquired by the optical acquisition means 12.

Claims

1. A method to calibrate a valve of a gas boiler, the valve (2) comprising at least one movable calibration element (2a, 2b), the method comprising:

   - connecting measuring instruments (5) to the gas boiler (1) in order to measure operating parameters of the gas boiler;
   - carrying out an adjustment cycle of the calibration element (2a, 2b) based on at least one measured parameter by means of a tool (13a,

13) which is couplable to the calibration element (2a, 2b);

and being **characterized in that** it comprises:

- acquiring at least one 3D image of the valve (2) by means of optical acquisition means (12);
- identifying position and orientation of the calibration element (2a, 2b) from the 3D image;
- calculating, based on position and orientation of the calibration element (2a, 2b), an approaching path of the tool (13a, 13b) to the calibration element (2a, 2b), which ends with a correct coupling between the tool (13a, 13b) and the calibration element (2a, 2b);
- moving the tool (13a, 13b) along the approaching path by means of an anthropomorphic robot (8) until the tool (13a, 13b) is coupled to the calibration element (2a, 2b);
- operating the tool (13a, 13b) to adjust the calibration element (2a, 2b) based on the measured parameter to carry out said adjustment cycle.

2. A method according to claim 1, wherein said optical acquisition means (12) are carried by said anthropomorphic robot (8).

3. A method according to claim 2, wherein said optical acquisition means (12) comprise a laser scanner emitting a planar light beam (15) to acquire a corresponding two-dimensional profile; acquiring at least one 3D image of the valve (2), comprising:

- moving said laser scanner along an acquisition path, which is orthogonal to said planar light beam (15) by means of said anthropomorphic robot (8) to acquire a plurality of two-dimensional profiles of said part of the valve (2); and
- combining said plurality of profiles to obtain said 3D image.

4. A method according to any one of the claims from 1 to 3, wherein said optical acquisition means (12) comprise a time-of-flight camera or a Range Sensor and are held in a stationary position in front of said valve (2).

5. A method according to any one of the claims from 1 to 4, wherein said calibration element is a screw (2a, 2b) and said at least one tool (13a, 13b) is motor-driven so as to rotate around a rotation axis (13c) and comprises an axial end which is couplable to the head of the screw (2a,2b).

6. A method according to claims 2 and 5, wherein said optical acquisition means (12) and said at least one tool (13a, 13b) are carried by a support (11) fitted on the wrist (10) of said anthropomorphic robot (8) and the optical acquisition means (12) comprise an optical axis (12a), which is transverse to a direction that is parallel to said rotation axis (13c); moving the tool (13a, 13b) along the approaching path, until the tool (13a, 13b) is coupled to the calibration element (2a, 2b), comprising:

- rotating the wrist (10) around a further rotation axis (17), which is perpendicular to a plane on which said direction and said optical axis (12a) lie, so that the rotation axis (13c) of the tool is parallel to an axis of said screw (2a, 2b).

7. An apparatus to calibrate a valve (2) of a gas boiler, the valve (2) comprising at least one movable calibration element (2a, 2b), the apparatus (3) comprising measuring instruments (5) which is connectable to the gas boiler (1) in order to measure operating parameters of the gas boiler (1), and at least one tool (13a, 13b) which is couplable to the calibration element (2a, 2b) so as to carry out an adjustment cycle of the calibration element (2a, 2b) based on at least one measured parameter, and being **characterized in that** said tool (13a, 13b) is motor-driven and **in that** it comprises: optical acquisition means (12) to acquire at least one 3D image of the valve (2); an anthropomorphic robot (8), which carries said tool (13a, 13b), and processing and controlling means (14; 7), which are configured to identify position and orientation of the calibration element (2a, 2b) from the 3D image, to calculate, based on position and orientation of the calibration element (2a, 2b), an approaching path of the tool (13a, 13b) to the calibration element (2a, 2b), which ends with a correct coupling between the tool (13a, 13b) and the calibration element (2a, 2b), to control the anthropomorphic robot (8) so as to move the tool (13a, 13b) along the approaching path until the tool (13a, 13b) is coupled to the calibration element (2a, 2b), to acquire the parameter measured by the measuring instruments (5) and to operate the tool (13a, 13b) to adjust the calibration element (2a, 2b) based on the measured parameter so as to carry out said adjustment cycle.

8. An apparatus according to claim 7, wherein said anthropomorphic robot (8) comprises a movable wrist (10) and a support (11) fitted on the wrist (10); said at least one tool (13a, 13b) being fitted on the support (11).

9. An apparatus according to claim 7 or 8, wherein said optical acquisition means (12) are fitted on said support (11).

10. An apparatus according to any one of the claims from 7 to 9, wherein said calibration element is a screw (2a, 2b) and said at least one tool (13a, 13b) is motor-driven so as to rotate around a rotation axis (13c) and comprises an axial end that can be coupled to the head of the screw (2a,2b).

11. An apparatus according to any one of the claims from 7 to 10, wherein said optical acquisition means (12) comprise a laser scanner emitting a planar light beam (15); said processing and controlling means (14; 7) being configured to move said laser scanner along an acquisition path, which is orthogonal to the planar light beam (15) so as to acquire a plurality of two-dimensional profiles of said part of the valve (2) and to combine said plurality of profiles in order to obtain said 3D image.

12. An apparatus according to any one of the claims from 7 to 10, wherein said optical acquisition means (12) comprise a time-of-flight camera or a Range Sensor.

13. An apparatus according to claims 8, 9 and 10, wherein said optical acquisition means (12) comprise an optical axis (12a) lying on a first plane, which is transverse to a second plane on which said rotation axis (13c) lies; said processing and controlling means (14; 7) being configured to control said anthropomorphic robot (8) in order to rotate the support (11) around a further rotation axis (17) defined by the intersection of the first plane with the second plane, so that the rotation axis (13c) is parallel to an axis of said screw (2a, 2b).

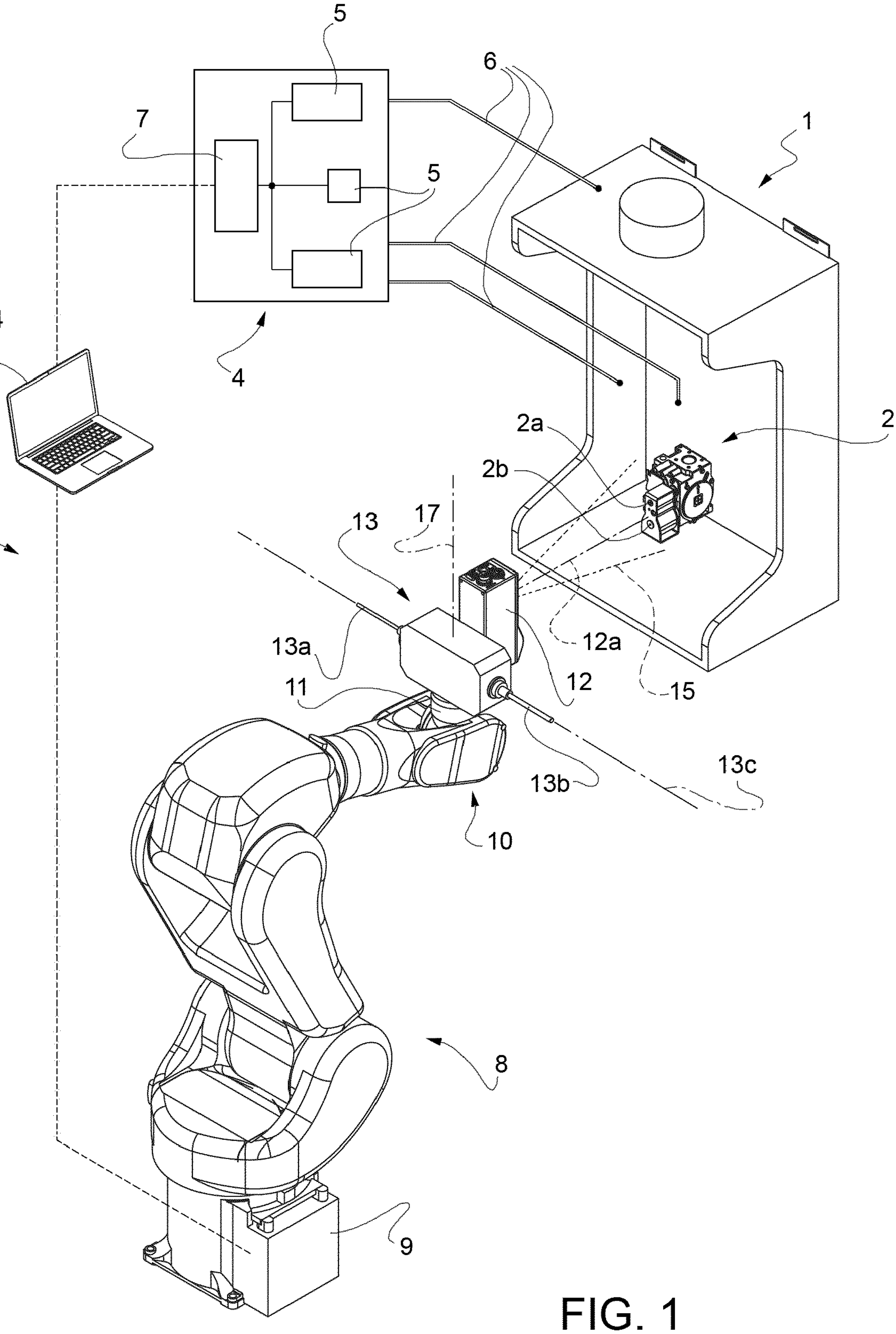

FIG. 1

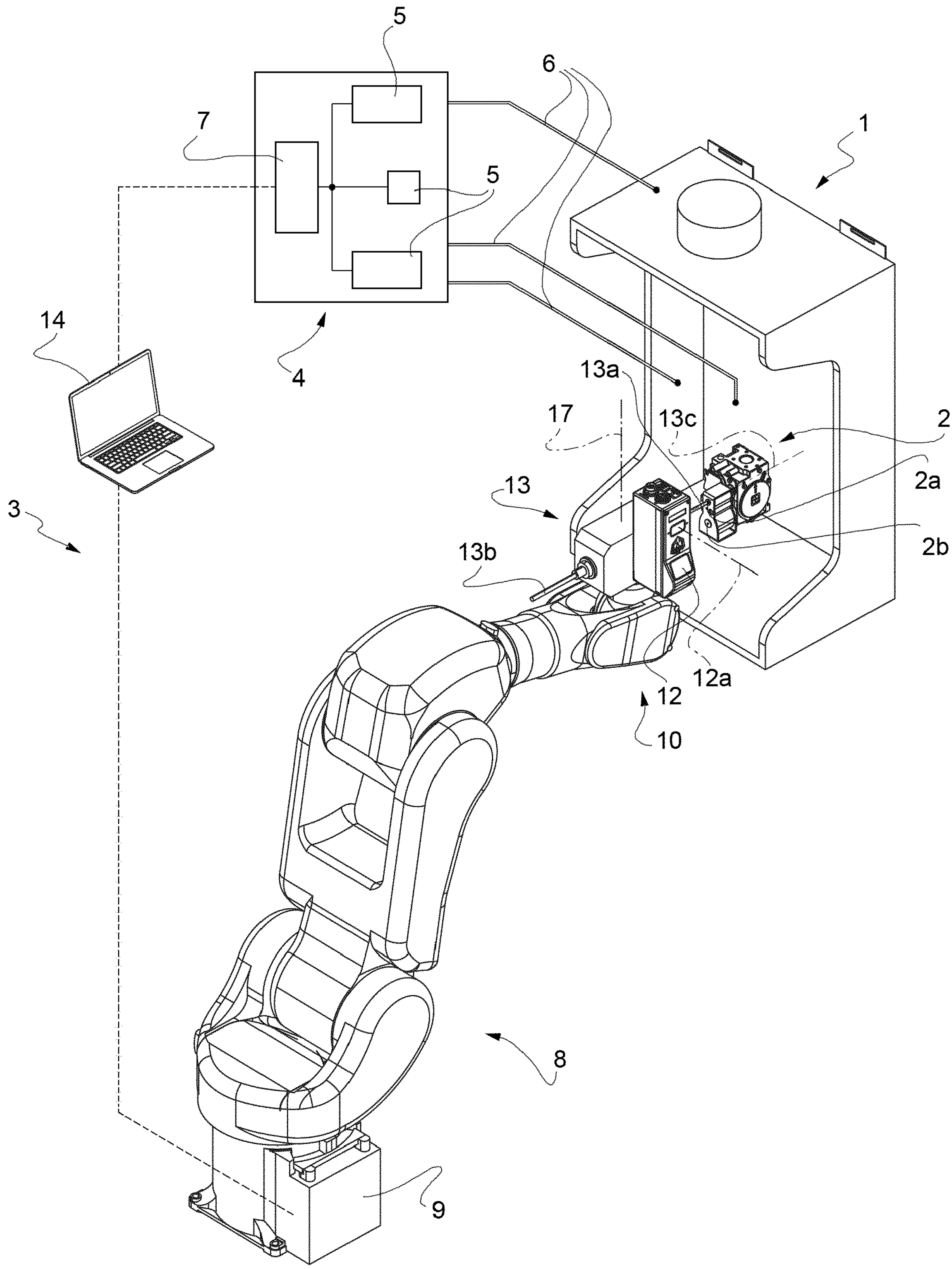

FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 18 16 1857

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

G12B
F23N

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	17 July 2018	Theis, Gilbert

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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