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

(11) **EP 4 506 965 A2**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
12.02.2025 Bulletin 2025/07

(21) Application number: **24188825.4**

(22) Date of filing: **16.07.2024**

(51) International Patent Classification (IPC):
G21K 5/00 *(2006.01)* *H01J 41/04* *(2006.01)*

(52) Cooperative Patent Classification (CPC):
G21K 5/00; H01J 41/04

(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:
GE KH MA MD TN

(30) Priority: **07.08.2023 EP 23189920**

(71) Applicant: **Tetra Laval Holdings & Finance S.A.**
1009 Pully (CH)

(72) Inventors:
- **CLOETTA, Dominique**
  3175 Flamatt (CH)
- **WANDFLUH, Wilhelm**
  3175 Flamatt (CH)

(74) Representative: **Tetra Pak - Patent Attorneys SE**
AB Tetra Pak
Patent Department
Ruben Rausings gata
221 86 Lund (SE)

(54) **CONTROL DEVICE FOR CONTROLLING THE OPERATIONAL EFFICIENCY OF AN IRRADIATION BEAM EMITTING DEVICE AND METHOD FOR CONTROLLING THE OPERATIONAL EFFICIENCY OF SAID IRRADIATION BEAM EMITTING DEVICE**

(57) It is disclosed a control device (1) for controlling the operational efficiency of an irradiation beam emitting device (2), wherein the irradiation beam emitting device (2) comprises a vacuum chamber (13), a filament (4) configured to emit electrons by thermionic effect, when heated, a first electrical conductor (6) and a second electrical conductor (5), said filament (4), first conductor (6) and second conductor (5) being placed inside the vacuum chamber (13),
the control device (1) comprising:
- a power supply (9) connectable to the filament (4), to the first conductor (6) and to the second conductor (5) to supply power to the filament (4), to the first conductor (6), and to the second conductor (5);
- a sensing unit (11) comprising at least a first sensor (7) configured to detect at least an electric parameter associated to a current flowing through the first conductor (6), defined as ionization current (IC), and a second sensor (8) configured to detect at least an electric parameter associated to a current flowing through the second conductor (5), defined as an emission current (EC);
- a control unit (10) coupled to the sensing unit (11) to receive the detected electric parameters and to the power supply (9) and further configured for actuating a main control mode (F1) of the status of the irradiation beam emitting device (2) comprising:
- adjusting the power supply (9) to apply on the filament (4) a predetermined current to emit electrons;
- adjusting the power supply (9) to apply a predetermined voltage on the first conductor (6);
- adjusting the power supply (9) to apply a predetermined voltage on the second conductor (5);
- deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) as a function of the detected electric parameter associated to the ionization current (IC) and of the detected electric parameter associated to the emission current (EC).

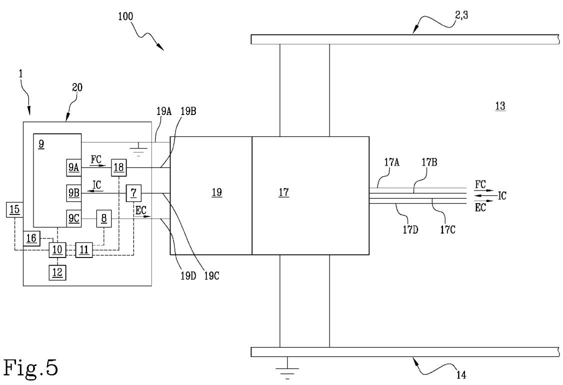

Fig.5

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Description

TECHNICAL FIELD

[0001] The present invention relates to a control device and a method for controlling the operational efficiency of an irradiation beam emitting device, allowing to make a diagnosis on such device.

[0002] The irradiation beam emitting device could be in particular employed in a sterilization apparatus, for example for the sterilization of a material, in particular a packaging material having a multilayer structure or a pharmaceutical material.

BACKGROUND ART

[0003] in the following, we will refer to the technical field of the sterilization of a packaging material; it is understood that the invention is applicable in the sterilization of other materials where irradiation beam emitting devices are used. Many liquid or pourable food products, such as fruit juice, UHT (ultra-high-temperature treated) milk, wine, tomato sauce, etc., are sold in packages made of sterilized packaging material.

[0004] The packaging material has a multilayer structure comprising a base layer, e.g. made of paper or cardboard, covered on both sides with layers of heat-seal plastic material, e.g. polyethylene.

[0005] Packages of this kind are normally produced on fully automatic packaging apparatuses, which advance and sterilize a web of packaging material, which is then formed into a tube and filled with the pourable pre/sterilized product under aseptic conditions before its formation into individually sealed packages.

[0006] Therefore, the typical automatic packaging apparatuses also comprise a respective sterilization apparatus so as to sterilize the web of packaging material, before it is formed and filled with the pourable pre/sterilized product.

[0007] Figure 1 shows the typical configuration of such pack sterilization apparatus, which has a first irradiation beam emitting device to sterilize the web of packaging material on a first face and a second irradiation beam emitting device to sterilize the web of packaging material on a second face, opposite to the first face.

[0008] Each irradiation beam emitting device comprises a main isolated housing having an inner space that defines a vacuum chamber full of gas under vacuum pressure and an exit window. The irradiation beam emitting device has an irradiation transmission source arranged within the vacuum chamber and configured to generate an electron beam and to direct the electron beam through the exit window and out of the vacuum chamber, towards one face of the web of packaging material.

[0009] Known sterilization apparatus must maintain a continuous optimal operation of the irradiation beam emitting device.

[0010] Indeed, the sterilizing effect is closely associated with the dose, i.e., the amount of emitted energy.

[0011] The vacuum pressure of the vacuum chamber of such an irradiation beam emitting device is intricately linked to the amount of emitted energy of the electron beam, thus is linked to the dose of emitted energy.

[0012] The maintenance of an appropriate vacuum pressure inside the vacuum chamber is thus crucial for the optimal performance and operation of the irradiation beam emitting device.

[0013] In fact, the vacuum pressure directly affects the trajectory and behavior of the emitted electron beams during the irradiation process.

[0014] Specifically, a controlled vacuum environment helps in minimizing the scattering and collision of electrons with gas molecules present in the chamber. These interactions can significantly alter the path and energy distribution of the electron beams, thereby affecting the efficacy and accuracy of the irradiation process.

[0015] By maintaining a suitably low vacuum pressure within the vacuum chamber of the irradiation beam emitting device, the likelihood of electron-gas molecule interactions is reduced. This allows for improved control over the emission of electron beams, ensuring their stable and predictable trajectories. Additionally, a well-controlled vacuum pressure inside the vacuum chamber helps minimize undesirable effects such as electron deflection, beam divergence, or loss of energy, which can compromise the intended irradiation outcomes.

[0016] Therefore, the vacuum pressure of the vacuum chamber plays a critical role in facilitating the emission of electron beams with optimal characteristics, ultimately influencing the performance and effectiveness of the irradiation beam emitting device.

[0017] There exists a pronounced demand within the industry for a control device that facilitates straightforward, rapid, and precise monitoring of the operational efficiency of a sterilization apparatus incorporating an irradiation beam emitting device.

DISCLOSURE OF INVENTION

[0018] The objective of the present invention is therefore to address the aforementioned need by providing a device and a control method for an irradiation beam emitting device that enables effortless, expeditious, and accurate monitoring of the state of the irradiation beam emitting device.

[0019] Moreover, the object of the present invention is to offer a device and a control method for checking the status of an irradiation beam emitting device for remarkably uncomplicated, fast, and accurate monitoring of the pressure state of the irradiation beam emitting device.

[0020] The technical features of the invention, in accordance with the stated objectives, are clearly discernible from the content of the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The advantages of the invention will be more conspicuously evident in the ensuing detailed description, accompanied by reference to the appended drawings, which represent a purely exemplary and non-limiting embodiment, wherein:

- Figure 1 schematically depicts a sterilization apparatus, to which is applied the control device object of the invention, in accordance with the prior art;
- Figure 2 represents, in a cross section view, the irradiation beam emitting device incorporated in the sterilization apparatus of figure 1 to which is applied the control device object of the invention;
- Figure 3 represents, in a schematic cross section view, some components of the irradiation beam emitting device of figure 2;
- Figure 4 shows, in a prospective view, the irradiation beam emitting device of figure 2;
- Figure 5 shows, in a schematic cross section view, the control device object of the invention applied to the irradiation beam emitting device of figure 2;
- Figure 6 represents, in a schematic view, a flow chart illustrating the control method according to the invention;
- Figure 7 depicts a schematic representation of a graph illustrating the interrelationships among various electrical characteristics upon which the control method of the invention is founded.

BEST MODES FOR CARRYING OUT THE INVENTION

[0022] The invention concerns a control (diagnosis or monitoring) device 1 for controlling the operational efficiency of an irradiation beam emitting device 2.

[0023] Preferably, but not limited to, the control device 1 according to the invention is applied to an irradiation beam emitting device 2 of a sterilization apparatus 3 for the sterilization of a (packaging) material PM.

[0024] More precisely, according to a non-limiting example, the packaging material PM is in the form of a web and is fed to sterilization apparatus 3 by known means, which are not shown or illustrated.

[0025] The sterilization apparatus 3 comprises, preferably, a first irradiation beam emitting device 2 and a second irradiation beam emitting device 2, according to the configuration shown in figure 1.

[0026] For simplicity, hereinafter, reference will be made to a single irradiation beam emitting device 2, without loss of generality; It is understood that the irradiation beam emitting device 2 can be utilized with various apparatuses employed for purposes of sterilization.

[0027] The irradiation beam emitting device 2 comprises a filament 4 configured to emit, when heated, by thermionic effect, electrons EB.

[0028] The irradiation beam emitting device 2 further comprises a first electrical conductor 6 (in the following referred simply as first conductor 6) and a second electrical conductor 5 (in the following referred simply as second conductor 5).

[0029] Preferably, the first conductor 6 is one of the cathode or the grid of the irradiation beam emitting device 2 and the second conductor 5 is the other of the grid or the cathode of the irradiation beam emitting device 2. In the illustrated embodiment, the first conductor 6 is the grid and the second conductor 5 is the cathode of the irradiation beam emitting device 2.

[0030] The first conductor 5 is electrically insulated from the second conductor 6.

[0031] The irradiation beam emitting device 2 further includes a housing 14 that encapsulates a vacuum chamber 13. The housing 14 is typically constructed from ceramic or a similar material to ensure voltage isolation from the exterior to the components inside the vacuum chamber 13, namely the filament 4, the first conductor 6 and the second conductor 5, located within the vacuum chamber 13. Please note that, according to an embodiment not shown in the drawings, one of the first conductor 6 or the second conductor 5 could be the housing 14.

[0032] It is important to emphasize that the first conductor 6 or the second conductor 5 are arranged in a way that they enclose a volume of gas.

[0033] This gas, as will be explained in more detail later, is ionized due to the electrons emitted by the filament 4.

[0034] According to the invention, the control device 1 comprises a power supply 9 connected (e.g. directly or indirectly) to the filament 4, to the first conductor 6 and to the second conductor 5 to supply power to all of them and to apply a predetermined voltage difference to the first conductor 6 and second conductor 5 to define an electric field between the first conductor 6 and second conductor 5. The term "power supply" refers to any power source capable of regulating voltages and/or currents of one or more outputs.

[0035] The power supply 9 defines an electrical source.

[0036] Such power supply 9 is configured to be connected (e.g. directly or indirectly) to the power grid network, or alternatively equipped with a battery to supply power.

[0037] It should be noted that the power supply 9 can comprise, as depicted in Figure 5, multiple power units (9A, 9B, 9C) that supply power namely to the filament 4, the first conductor 6, and the second conductor 5 respectively. For instance, the power supply 9 can comprise a first power unit 9A that supplies power to the filament 4, a second power unit 9B to supply power to the first conductor 6, and a third power unit 9C to supply power to the second conductor 5.

[0038] The phrase "supply power" indicates that the power units (9A, 9B, 9C) are configured to regulate the electrical voltage and/or current in order to provide energy to the elements (filament 4, first conductor 6, or second conductor 5) connected to them.

[0039] According to an aspect, the first power unit 9A is a power supply configured to apply a predetermined and adjustable current to the filament 4, when connected to the filament 4.

[0040] Preferably, the first power unit 9A is connectable to the filament 4 by means of a couple of wires, identifies by reference 19B and 19A (ground) in figure 5.

[0041] Subsequently, the connection between the power supply 9 and the electrical components (filament 4, first conductor 6, or second conductor 5) of the irradiation beam emitting device 2 will be described in more detail.

[0042] According to an aspect, the second power unit 9B is configured to apply a predetermined and adjustable first (preferably negative) voltage to the first conductor 6, when connected to the first conductor 6.

[0043] Preferably, the second power unit 9B is connectable to the first conductor 6 using a couple of wires, identifies by reference 19C and 19A (ground) in figure 5. According to an aspect, the third power unit 9C is configured to apply a predetermined and adjustable second (preferably positive) voltage to the second conductor 5, when connected to the second conductor 5.

[0044] Experimental tests conducted by the Applicant has shown that the optimal configuration, which minimizes error noise in deriving the status parameter and allows for the most accurate diagnosis, is achieved when the voltage of the second electrical conductor 5 is positive (greater than zero) and the voltage of the first electrical conductor 6 is negative (lower than zero).

[0045] In particular, experimental tests pointed out that the optimal configuration is reached when the cathode, as second electrical conductor 5, is polarized positive and the grid, as first electrical conductor 6, is polarized negative.

[0046] Thus, in a preferred configuration, the voltages of the first and second conductor (5,6) exhibit opposite signs, that means that one of predetermined voltage on the first conductor 6 and the predetermined voltage on the second conductor 5 is positive and the other of predetermined voltage on the second conductor 5 and the predetermined voltage on the first conductor 6 is negative.

[0047] Specifically, the electrons emitted by filament 4 are drawn towards the respective conductor (either second conductor 5 or first conductor 6) which has a positive voltage applied thereon, whereas the positive ions produced during the gas ionization process are attracted to their respective counterpart element (either first conductor 6 or second conductor 5) which has a negative voltage applied thereon.

[0048] Preferably, the third power unit 9C is connectable to the second conductor 5 by means of a couple of wires, identifies by reference 19D and 19A (ground) in figure 5.

[0049] According to the invention, the control device 1 further comprises a sensing unit 11, comprising at least a first sensor 7 configured to detect at least an electric parameter associated to a current flowing through the grid 6, defined as ionization current IC, and a second sensor 8 configured to detect at least an electric parameter associated to a current flowing through the second conductor 5, defined as emission current EC. In particular, the emission current is a current created by the electrons emitted by the filament 4. In particular, the ionization current is the current created by the positive ions produced during gas ionization. Preferably, the first sensor 7 and the second sensor 8 are current sensors. According to the invention, the control device 1 comprises a control unit 10 coupled to the sensing unit 11 to receive the detected electric parameters.

[0050] The control unit 10 is further connected (e.g. directly or indirectly) to the power supply 9 to adjust one or more electrical parameters of the latter (output voltage, output currents, etc.).

[0051] Further, the control device 1 comprises a housing 20, defined for example by a box of any shape, which contains the electrical components of the control device 1, such as the above cited power supply 9, the sensing unit 11 and the control unit 10.

[0052] The housing 20 preferably includes at least a handle.

[0053] Further, the housing 20 is configured to be portable.

[0054] Indeed, the control device 1 can be conveniently brought near the irradiation beam emitting device 2 in the event that diagnosis or monitoring of the operational efficiency of the irradiation beam emitting device 2 is required. According to the invention, the control unit 10 is configured for actuating a main control mode F1 of the status of the irradiation beam emitting device 2 comprising:

- adjusting the power supply 9 to apply to the filament 4 a predetermined current to emit electrons;
- adjusting the power supply 9 to apply a predetermined (preferably positive) voltage on the second conductor 5;
- adjusting the power supply 9 to apply a predetermined (preferably negative) voltage on the first conductor 6;
- deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 as a function of the detected electric parameter associated to the ionization current IC and of the detected electric parameter associated to the emission current EC.

[0055] Please note that, when the control unit 10 adjusts the power supply 9 to apply a predetermined (preferably negative) voltage on the first conductor 6 and adjusts the power supply 9 to apply a predetermined (preferably positive) voltage on the second conductor 5, a positive electric field is defined between the second conductor 5 and the first conductor 6.

[0056] Preferably, the control unit 10 adjusts the power supply 9 to apply to the second conductor 5 a voltage over 200 V (more preferably, comprised between 200 V and 1500 V).

[0057] Preferably, the control unit 10 adjusts the power supply 9 to apply a voltage to the first conductor 6 between -25 V and - 150 V.

[0058] In the following, we will provide a more detailed description of how the aforementioned control unit 10 configuration is enabling the specific advantages of the invention, thereby also addressing the previously defined technical problem.

[0059] When an electron current traverses a low-pressure gas medium, collisions occur between the electrons and gas molecules. In the presence of an adequate electron energy, ionization of the gas molecules occurs, leading to an ionization current. The magnitude of this ionization current is directly influenced by the vacuum pressure of the vacuum chamber 13, exhibiting an increase as the pressure rises.

[0060] According to the invention, the filament 4, subjected to a filament current FC, is heated to a temperature that enables thermionic emission.

[0061] By applying a positive electric potential (voltage) to the second conductor 5, the electrons emitted by the filament 4 are attracted by the second conductor 5 and subsequently accelerated to energies sufficient for ionizing the gas molecules within the vacuum chamber 13 of the irradiation beam emitting device 2.

[0062] Both the original electrons (that are the electrons emitted by the filament 4) and those generated during ionization proceed along their path towards the second conductor 5, where they are ultimately absorbed. Conversely, the positively charged ions resulting from the collisions are accelerated towards the first conductor 6 which has a negative electric potential (i.e. voltage).

[0063] As will be more deeply discussed, it has been found experimentally by the applicant that the relationship between the emission current (EC, defined by electrons moving towards the second conductor 5) and the ionization current (IC, defined by ions moving towards the first conductor 6) is dependent on the vacuum pressure magnitude of the vacuum chamber 13.

[0064] Figure 7 depicts a graph illustrating curves (C1, C2, C3, C4) representing the relationship between the emission current EC and the ionization current IC for different vacuum chamber pressures of the vacuum chamber 13. It should be noted that the curve C1 corresponds to a pressure of 1e^-5 mbar, curve C2 corresponds to a pressure of 1e^-6 mbar, while curves C3 and C4 correspond to pressures of 1e^-7 mbar and 1e^-8 mbar, respectively. The graph in figure 7 has been experimentally obtained by the applicant, who conducted tests on various irradiation beam emitting devices 2 having different vacuum pressure inside the vacuum chamber 13.

[0065] In particular, the applicant has experimentally observed that, for a predetermined emission current EC, the ionization current IC increases with increasing pressure inside the vacuum chamber 13.

[0066] In other words, it has been experimentally observed by the applicant that the linear relationship, obtained by interpolating experimental points of emission current EC and ionization current IC measured through sensing unit 11 (EC; IC), has a slope (angular coefficient) which increases with increasing pressure inside the vacuum chamber 13.

[0067] Therefore, it has been found that the ratio between the emission current EC and the ionization current IC is proportional to the vacuum pressure inside the vacuum chamber 13: the higher the vacuum pressure, the greater the aforementioned ratio.

[0068] The above cited parameter representing an operational efficiency of the irradiation beam emitting device 2 could be, for example, one of the following:

- the ratio between the emission current EC and the ionization current IC;
- the pressure inside the vacuum chamber 13;
- the ionization current IC value for a predetermined emission current EC value. Please note that the parameter representing an operational efficiency of the irradiation beam emitting device 2 is a parameter whose value is associated, directly or indirectly, with the vacuum pressure of the vacuum chamber 13.

[0069] It is important to note that the first sensor 7 specifically measures the ionization current IC flowing through the first conductor 6 due to the voltage applied by the power supply 9, particularly by the second power unit 9B.

[0070] Instead, the second sensor 8 specifically measures the emission current EC flowing through the second conductor 5 due to the voltage applied by the power supply 9, particularly by the third power unit 9C.

[0071] Preferably, the housing 14 is at a voltage of 0 V (corresponding to the ground voltage).

[0072] Further, when a current is applied to the filament 4, its voltage (in at least one point of it or in at least one point of its feeding conductors) is 0 V.

[0073] According to one aspect, the control unit 10 is configured for:

- adjusting the power supply 9 to apply on the filament 4, at different time instants, a plurality of predetermined different filament 4 current values FC, generating a plurality of different electron beam emissions,
- deriving the cited status parameter as a function of the detected electric parameter associated to the ionization current IC and the detected electric parameter associated to emission current EC taken from the sensing unit 11 at the different filament 4 current values.

[0074] It is observed that by varying the filament current FC, different emission currents EC and ionization currents IC are obtained, thus allowing for a plurality of different emission current EC / ionization current IC pairs to be achieved (preferably, at least two pairs).

[0075] Preferably, the control unit 10 is configured to derive a predetermined mathematical relationship between the detected emission current / ionization current pairs (also defined as EC/IC current pairs), such as determining the slope or angular coefficient of a linear relationship that associates (preferably interpolates) said EC/IC current pairs.

[0076] As previously described, the slope or angular coefficient of a linear relationship that associates (preferably interpolates) said EC/IC current pairs is correlated or proportional to the vacuum pressure of the gas inside the vacuum chamber 13.

[0077] In other words, the derived slope or angular coefficient measurement is an indication of the gas vacuum pressure inside the vacuum chamber 13, being representative of the state of the irradiation beam emitting device 2.

[0078] Please note that, preferably, the control unit 10 is configured to adjust the filament current FC value at predetermined steps, each step being comprised between 0.05 and 0.2 A, starting from a first low value of filament current (preferably comprised between 3 and 7 A).

[0079] It is observed that, generally, the emission current EC for such filament current FC values is lower than a predetermined current value, preferably 20 mA.

[0080] According to another aspect, the control unit 10 is configured to derive at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 at a predetermined high value of emission current EC, preferably comprised between 10 mA and 30 mA, as a function of the detected electric parameter associated to the ionization current IC and the detected electric parameter associated to the emission current EC.

[0081] In other words, in accordance with this aspect, it is not necessary to have current EC/IC pairs of values, but it is sufficient to detect a single value of the ionization current IC for a predetermined value of the emission current EC.

[0082] It is understood that the predetermined value of the emission current EC can be obtained by driving or setting the filament current (FC) value appropriately through the control unit 10.

[0083] According to another aspect, the control device 1 comprises a (permanent i.e. not volatile) memory 12, connected (e.g. directly or indirectly, wirelessly or in a cabled way) to, or integrated in, the control unit 10, for storing at least a reference parameter (or, preferably, a plurality of reference parameters).

[0084] According to such aspect, the control unit 10 is configured to derive the at least one status parameter representing an operational efficiency of the irradiation beam emitting device 2 as a function of the detected electric parameters associated to the ionization current IC and the emission current EC as well as of the at least one reference parameter stored in the memory 12.

[0085] Please note that the detected electric parameters associated to the ionization current IC and emission current EC are compared with the at least one reference parameter stored in the memory 12.

[0086] According to a further aspect, the at least one reference parameter defines a relationship between ionization current IC and emission current EC with respect to the vacuum pressure inside the vacuum chamber 13 of the irradiation beam emitting device 2.

[0087] Preferably, according to the matter disclosed above with reference to the figure 7, such at least one reference parameter comprises at least a value (preferably a plurality of values) defining a mathematical linear relationship (e.g. a slope) between the ionization current IC and the emission current EC with respect to different vacuum pressure inside the vacuum chamber 13 of the irradiation beam emitting device 2.

[0088] Please further note that the control device 1 has a user interface 15.

[0089] The user interface 15 is connected with the control unit 10, for sending user commands, and/or receiving data from the control unit 10.

[0090] Further, preferably the user interface 15 is configured to display data received from the control unit 10

[0091] Preferably, the user interface 15 comprises a screen.

[0092] Preferably, the user interface 15 comprises buttons, activable by the user to send commands.

[0093] Further, the control device 1 comprises a communication module 16 configured to transmit and /or receive data.

[0094] According to one aspect, the communication module 16 is preferably connected with the control unit 10 to retrieve data from the control unit 10 in order to transmit the data comprising, for example, one or more of the following: the values of the electric parameters detected by the sensing unit 11, the status parameter representing an operational efficiency of the irradiation beam emitting device 2, the setting of the power supply 9, etc.

[0095] In the following, additional aspects of the invention will be described, which constitute optional features that, advantageously, allow for increasing the potential and overall reliability of the control device 1, enabling it to perform additional diagnostic checks and identify additional irradiation beam emitting device 2 failure modes.

[0096] It should be noted that these additional control modes, which the control device 1 is capable of implementing, are carried out at different time intervals than described previously (which corresponds to main control mode F1 as shown in figure 6).

[0097] In the following, when introducing an additional control mode, explicit reference will be made to the procedure depicted in figure 6 to provide context within

Figure 6.

[0098] It should be noted, however, that although figure 6 describes these additional control modes in a sequential implementation according to the shown flowchart, it does not preclude the possibility that these additional control modes can be independently executed, even according to a different sequential implementation. In other words, the control unit 10 can be configured to implement, in addition to the main control mode F1 which is the core of the invention, one or more of the control modes that will be described subsequently.

[0099] According to another aspect, the sensing unit 11 comprises a third sensor 18, configured to detect an electric parameter associated to the voltage applied to the filament 4.

[0100] It is noted that the presence of this additional third sensor 18 allows for the implementation of a further control mode F2, as described below.

[0101] In accordance with this further control mode F2, the control unit 10 is configured to:

- adjust the power supply 9 to apply to the filament 4 a plurality of different predetermined currents, defined as filament current FC;
- derive at least a filament 4 status parameter, representing the operational efficiency of filament 4 of the irradiation beam emitting device 2, as function of the detected electric parameter associated to the voltage applied to the filament 4 with respect to the filament current FC.

[0102] According to this control mode F2, the control unit 10 is configured to adjust the power supply 9 such that the voltage at the second conductor 5 and the first conductor 6 is zero, that is, 0V.

[0103] Preferably, according to this control mode F2, the control unit 10 is configured to adjust the power supply 9 in order to increment the filament current FC in predetermined steps (preferably ranging from 0.05 A to 0.2 A), up to a high predetermined value of filament current FC (preferably ranging from 4 A to 6 A).

[0104] Preferably, the control unit 10 is configured to detect, by means of the third sensor 18, the filament 4 voltage at this high predetermined value of filament current FC and to make the comparison based on such detected filament 4 voltage at this high predetermined value of filament current FC.

[0105] More generally, regardless of the implementation details of this further control mode F2, it is observed that this control mode F2 allows determining whether the pressure inside the vacuum chamber 13 is above a predetermined value or not.

[0106] In fact, if the filament voltage FC detected by the third sensor 18, for a predetermined filament current FC, is too high (corresponding to condition F2B in figure 6), it indicates that the pressure inside the vacuum chamber 13 is substantially equal to the ambient pressure, meaning there is no vacuum inside the vacuum chamber 13.

[0107] Conversely, if the filament voltage FC detected by the third sensor 18, for a predetermined filament current FC, is equal to or lower than a predetermined value (corresponding to condition F2A in figure 6), it indicates that the pressure inside the vacuum chamber 13 is within the optimal operating specifications of the irradiation beam emitting device 2.

[0108] Thus, the control unit 10 is further configured to derive an indication of vacuum pressure inside the vacuum chamber 13 of the irradiation beam emitting device 2, based on said derived filament 4 status parameter, in particular to derive if such vacuum pressure is equal to the ambient pressure or not.

[0109] Please note that such control mode F2 allows to check the filament 4 status. Preferably, according to one aspect, the control unit 10 is configured to execute the control mode F2 before the main control mode F1.

[0110] An additional control mode F3, corresponding to what is indicated in figure 6 within the rectangle F3, will be described below.

[0111] According to this additional control mode F3, the control unit 10 is configured to:

- adjust the power supply 9 to apply on the first conductor 6 a predetermined (preferably negative) voltage;
- adjust the power supply 9 to apply on the second conductor 5 a plurality of different predetermined (preferably positive) voltages;
- deriving at least a first conductor 6 - second conductor 5 status parameter representing an operational efficiency of the combination of the first conductor 6 - second conductor 5 based on the detected electric parameter associated to the ionization current IC and on the parameter associated to emission current EC.

[0112] According to one implementation of the above operating mode F3, the control unit 10 is configured to adjust the power supply 9 to apply a predetermined (negative) voltage, ranging from -80 V to -150 V, on the first conductor 6. Furthermore, according to another aspect of the above operating mode F3, the control unit 10 is configured to adjust the power supply 9 to apply a variety of different predetermined (positive) voltages on the second conductor 5 up to a predetermined second conductor 5 voltage value, preferably below 1000 V, and even more preferably below 900 V.

[0113] Preferably, the control unit 10 is configured to adjust the power supply 9 to apply a variety of different predetermined (positive) voltages on the second conductor 5 in steps, preferably each step ranging from 5 V to 50 V.

[0114] Please note that, more specifically, according to the control mode F3, the control unit 10 is configured to compare the detected electric parameter associated to the ionization current IC and the detected electric parameter associated to emission current EC to check if such ionization current IC and/or emission current EC are below a predetermined threshold; in case (condition F3A) the ionization current IC and/or emission current EC are below a predetermined threshold the status parameter representing an operational efficiency of the combination of first conductor 6 and second conductor 5 is set to a value representing an optimal operational efficiency of the combination of first conductor 6 and second conductor 5; otherwise, the status parameter representing an operational efficiency of the combination of first conductor 6 and second conductor 5 is set to a value indicating a technical problem resulting from such operational mode F3 (condition F3B).

[0115] Please note that a technical problem corresponding to the condition F3B could be a problem associated with the isolation of the housing 14 or to the pressure inside the vacuum chamber 13.

[0116] Hereinafter, an additional control mode F4 will be described, which can be implemented on control unit 10.

[0117] According to this further control mode, denoted as F4, the sensing unit 11 comprises a third sensor 18, configured to detect at least an electric parameter chosen from the group consisting of the voltage or current in the filament 4; further the control unit 10 is configured to:

- adjust the power supply 9 to apply to the filament 4, to the first conductor 6 or to the second conductor 5 predetermined relative electrical voltages or currents;
- conducting a cross comparison between a couple of the following elements: the filament 4, the first conductor 6, the second conductor 5 and a housing 14 enclosing the vacuum chamber 13, to check if there is a short circuit between any couple of the cross-compared elements by comparing one or more of the detected electric parameters, detected from the first sensor 7, the second sensor 8 or the third sensor 18 and one or more of the values of electrical voltages or currents applied by power supply 9 to the cross-compared elements.

[0118] In other words, the F4 control mode entails configuring the control unit 10 to perform a plurality of cross-checks, in pairs, among the filament 4, the first conductor 6, the second conductor 5 and the housing 14. The purpose of these cross-checks is to determine the presence of a short circuit between these pairs of elements.

[0119] Please note that in the event it becomes necessary to detect a short circuit between second conductor 5 and housing 14, sensors involving second conductor 5 will be employed, and power supply 9 will apply a predetermined current or voltage to second conductor 5.

[0120] The purpose of this control mode F4 is to detect any technical failures or malfunctions that may affect the operation of the main electrical components of irradiation beam emitting device 2, namely the filament 4, the first conductor 6, the second conductor 5 and the housing 14. Examples of such failures or malfunctions include, but are not limited to, filament 4 breakage that could come into contact with first conductor 6 or second conductor 5, or other issues between second conductor 5 and first conductor 6. The objective is to identify and address any potential problems that may arise among these key components to ensure the proper functioning of the irradiation beam emitting device 2.

[0121] Hereinafter, an additional control mode, referred to as F5 in figure 6, will be described. Advantageously, the control unit 10 can be configured to implement this specific additional control mode F5 as well.

[0122] According to this additional control mode F5, the sensing unit 11 comprises a third sensor 18, configured to detect an electric parameter chosen from the group consisting of the voltage or current in the filament 4.

[0123] Preferably, the third sensor 18 is configured to detect the voltage applied to the filament 4.

[0124] The control unit 10, according to this additional control mode F5, is configured to:

- adjusting the power supply 9 to apply to the filament 4 a predetermined value of an electric parameter chosen between voltage or current, said electric parameter chosen being different from the electric parameter detected by the third sensor 18;
- check if the filament 4 connection is broken based on the detected electric parameter, detected from third sensor 18, and on the predetermined value of the chosen voltage or current parameter applied to the filament 4.

[0125] It is noteworthy that, according to this control mode F5, if the third sensor 18 is a sensor configured to detect a voltage across the filament 4, then the control unit 10 is configured to adjust the power supply 9 to apply a predetermined value of current to the filament 4. On the other hand, if the third sensor 18 is a sensor configured to detect a current value flowing through the filament 4, then the control unit 10 is configured to adjust the power supply 9 to apply a predetermined value of voltage to the filament 4.

[0126] Please note that, according to this control mode F5, the control unit 10 is configured to determine a resistance value of the filament 4, by comparing the voltage applied to, and current flowing through, the filament 4, to check whether the filament 4 is broken or not.

[0127] In essence, the outcome of the comparison performed by the control unit 10 according to this additional control mode F5, is a status parameter that indicates the intactness or impairment of the filament 4. Therefore, the primary objective of control mode F5 is to verify the presence (condition indicated with F5B in figure 6) or absence (condition indicated with F5A in figure 6) of filament 4 breakage.

[0128] It should be noted that, regardless of the mode depicted in figure 6, the control unit 10 can be configured to implement, in addition to the main control mode F1, one or more of the control modes F2, F3, F4, and F5 described earlier, even with different temporal sequences than those illustrated in figure 6.

[0129] In a specific embodiment, the control unit 10 is configured to execute the control mode according to the sequence depicted in figure 6.

[0130] Please note that in case the control unit 10 is configured to execute a plurality of different control modes (F1, F2, F3, F4, F5), the control unit 10 is configured to switch between a control mode and another control mode, depending on the predetermined operating setting of the same control unit 10.

[0131] It is noteworthy that, particularly referring to figure 6, all conditions denoted by the suffix "B" (F2B, F3B, F4B, F5B) signify termination conditions within the control procedure shown in figure 6 and implemented by the control unit 10. In these termination conditions, the control unit 10 determines a status parameter which value is indicative of a malfunction or suboptimal performance of the irradiation beam emitting device 2.

[0132] The control device 1 further comprises a connector 19, which is configured to couple with a corresponding irradiation beam connector 17 placed in the housing 14 of the irradiation beam emitting device 2.

[0133] The connector 19 comprises a plurality of connection electrical wires (19A, 19B, 19C, 19D), which are configured to couples with corresponding electrical wires (17A,17B,17C,17D) of the irradiation beam connector 17 of the housing 14 of the irradiation beam emitting device 2.

[0134] Please note that the electrical wires (17A,17B,17C,17D) of the irradiation beam connector 17 are namely connected with the filament 4, the first conductor 6 and the second conductor 5.

[0135] Please further note that one of these electrical wires (17A,17B,17C,17D), in the drawings of figure 5 indicated with the reference 17A, could be used as a common ground (i.e. voltage zero) between the filament 4, the first conductor 6 and the second conductor 5.

[0136] The connector 19 could be easily and fast attached / detached from the corresponding irradiation beam connector 17.

[0137] Typically, during the use of the irradiation beam emitting device 2 to sterilize a material (e.g. a web of packaging material), the irradiation beam connector 17 is connected to a control connector (not shown), which provides appropriate voltages or currents to operate the irradiation beam emitting device 2 in a sterilization mode, where an electron beam is emitted.

[0138] By disconnecting the control connector from the irradiation beam connector 17 and attaching, in its place, the connector 19 of the control device 1, the maintenance technician can monitor the status of the irradiation beam emitting device 2

[0139] The control device 1 according to the invention presents a multitude of advantages.

[0140] Firstly, the control device 1 simplifies the maintenance and periodic monitoring procedure of the irradiation beam emitting device 2 to a remarkable extent. It obviates the need for disassembling the irradiation beam emitting device 2 from its mounting position to assess its operational efficiency. Instead, the control device 1 can be swiftly and easily connected on-site to the irradiation beam emitting device 2, enabling prompt determination of the status parameter.

[0141] This greatly reduce the downtime of the irradiation beam emitting device 2.

[0142] Furthermore, the control device 1 facilitates the implementation of one or more assisted and automated control procedures, thereby enabling even moderately skilled technical personnel to perform the operational efficiency assessment of the irradiation beam emitting device 2. This simplification of the maintenance process is highly advantageous.

[0143] Moreover, the control device 1 demonstrates exceptional effectiveness in the identification of multiple faults by virtue of its capability to employ distinct control modes (F1, F2, F3, F4, F5), each designed to detect specific technical faults.

[0144] In addition, the control device 1 facilitates optimal functioning of the irradiation beam emitting device 2, as it conducts a series of checks that guarantee the complete operational efficiency, efficacy, and sterilization capacity of the irradiation beam emitting device 2.

[0145] According to the invention, it is also disclosed a sterilization system 100 for the sterilization of a packaging material PM, comprising:

- a sterilization apparatus 3 for the sterilization of a (packaging) material PM, having an irradiation beam emitting device 2 comprising a vacuum chamber 13, a filament 4 configured to emit, when heated, by thermionic effect, electrons, a second conductor 5 and a first conductor 6, the filament 4, second conductor 5 and first conductor 6 being placed inside the vacuum chamber 13;
- a control device 1 for controlling the status of the irradiation beam emitting device 2, according to any of the appended claims.

[0146] According to the invention, it is further disclosed a method for controlling the operational efficiency of an irradiation beam emitting device 2.

[0147] The method could be applied to an irradiation beam emitting device 2 of a sterilization apparatus 3 for the sterilization of a (preferably packaging) material PM.

[0148] As above disclosed, the irradiation beam emitting device 2 comprises a filament 4 configured to emit, when heated, by thermionic effect, electrons, a first conductor 6 and a second conductor 5.

[0149] The filament 4, first conductor 6, and second conductor 5 are situated within a vacuum chamber 13, wherein a gas is enclosed under vacuum conditions.

[0150] The method, according to the invention, comprises the following phases defining a main control mode F1 of the status of the irradiation beam emitting device 2:

- adjusting a power supply 9 to apply, simultaneously, a predetermined current on the filament 4 to emit electrons, a predetermined (preferably positive) voltage on the second conductor 5 and a predetermined (preferably negative) voltage on the first conductor 6;
- detecting an electric parameter associated with a current flowing through the first conductor 6, defined as ionization current IC, and detecting an electric parameter associated with a current flowing through the second conductor 5, defined as emission current EC;
- deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 as a function of the detected electric parameter associated with the ionization current IC and the detected electric parameter associated with the emission current EC.

[0151] According to another aspect of the method, the phase of adjusting the power supply 9 to apply, simultaneously, a predetermined current on the filament 4 to emit electrons, a predetermined voltage on the second conductor 5 and a predetermined voltage on the first conductor 6 comprises the phase of adjusting the power supply 9 to apply on the filament 4, at different time instants, a plurality of predetermined different current values, generating a plurality of different electron emissions and wherein the phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 comprises a phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 as a function of the detected electric parameter associated to the ionization current IC and of the detected electric parameter associated to emission current EC taken at the different filament 4 current values.

[0152] According to another aspect, the phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 comprises a phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 at a predetermined high value of emission current EC, preferably comprised between 10 mA and 30 mA.

[0153] According to a further aspect, the phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 comprises a phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device 2 as a function of the ionization current IC, the emission current EC and at least a reference parameter.

[0154] Preferably, the at least one reference parameter defines a relationship between ionization current IC and emission current EC with respect to the vacuum pressure inside the vacuum chamber 13 of the irradiation beam emitting device 2. In other words, the at least one reference parameter comprises at least a value (e.g. ratio between the ionization current IC and the emission current EC) defining a mathematical linear relationship between the ionization current IC and the emission current EC with respect to different vacuum pressure inside the vacuum chamber 13 of the irradiation beam emitting device 2.

[0155] Now, a brief description will be provided of a setup procedure for the control device 1, enabling to execute the method of the invention with particular effectiveness on a specific irradiation beam emitting device 2.

[0156] According to the setup procedure, it is provided an initial setup phase of said at least one reference parameter which comprises a phase of providing a number of identical test irradiation beam emitting devices 2, each having a vacuum chamber 13 with a different internal vacuum pressure value. The possibility exists of using a single irradiation device and adjusting the internal vacuum pressure value, or the possibility exists of using a plurality of emitting devices 2 exhibiting different internal vacuum pressure values.

[0157] According to this aspect, the method further comprising the following phases, executed for at least one vacuum pressure value and/or each test irradiation beam emitting device 2:

- adjusting the power supply 9 to apply, e.g. simultaneously, a predetermined current on the filament 4 to emit electrons, a predetermined voltage on the first conductor 6 and a predetermined voltage on the second conductor 5;
- detecting at least an electric parameter associated to a current flowing through the first conductor 6, defined as ionization current IC, and detecting at least an electric parameter associated to a current flowing through the second conductor 5, defined as emission current EC,
- deriving said at least one reference parameter from said detected parameter associated with ionization current IC and from said detected parameter associated with emission current EC;
- storing said at least one reference parameter, preferably associated with the internal vacuum pressure value.

[0158] It should be noted that having prior knowledge of the vacuum pressure value inside the vacuum chamber 13 for each test irradiation beam emitting device 2 allows to establish, via the at least one reference parameter, an association between the vacuum pressure and the detected values of ionization current IC and emission current EC for a predetermined filament current FC.

[0159] Essentially, this aspect enables the derivation of at least one reference parameter that can be used to model the curves C1, C2, C3, C4 depicted in figure 7 for different vacuum pressures represented by the test irradiation beam emitting devices 2.

[0160] It is worth mentioning that this setup phase needs to be repeated when using the control device 1 with a different irradiation beam emitting device 2, which has different dimensions and characteristics.

[0161] Essentially, the setup or calibration phase allows for obtaining reliable reference parameters only applicable for monitoring an irradiation beam emitting device 2 identical to those subjected to testing.

[0162] According to another aspect, which corresponds to the matter previously disclosed with reference to the control mode F2 configuration of figure 6,
the method comprising the following phases:

- detecting an electric parameter associated to the voltage applied to the filament 4;
- adjusting the power supply 9 to apply to the filament 4 a plurality of different predetermined currents, defined as filament current FC;
- deriving a filament 4 status parameter, representing the operational efficiency of filament 4 of the irradiation beam emitting device 2 as a function of the detected electric parameter associated to the voltage applied to the filament 4 and the filament current FC.

[0163] According to a further aspect, the phase of deriving a filament 4 status parameter comprises a phase of deriving an indication of a vacuum pressure inside the vacuum chamber 13 of the irradiation beam emitting device 2 based on said filament 4 status parameter derived.

[0164] According to another aspect, which corresponds to the matter previously disclosed with reference to the control mode F3 configuration of figure 6, the method further comprises the following phases:

- adjusting the power supply 9 to apply to the first conductor 6 a predetermined voltage;
- adjusting the power supply 9 to apply to the second conductor 5 a plurality of different predetermined voltages;
- derive a first conductor (6) - second conductor (5) status parameter representing an operational efficiency of the combination of first conductor (6) and the second conductor (5) as a function of the detected electric parameter associated to the ionization current IC and the detected electric parameter associated to emission current EC.

[0165] According to another aspect, which corresponds to the matter previously disclosed with reference to the control mode F4 configuration of figure 6, the method further comprises the following phases:

- detecting an electric parameter chosen from the group consisting of the voltage or current in the filament 4;
- adjusting the power supply 9 to apply on the filament 4, on the second conductor 5 or on the first conductor 6 predetermined relative electrical voltages or currents;
- conducting a cross comparison between at least a couple of the following cross compared elements: the filament 4, the first conductor 6, the second conductor 5 and a housing 14 enclosing the vacuum chamber 13, to check if there is a short circuit between said couple of the cross-compared elements based on one or more of the detected electric parameter and on one or more of the electrical voltages or currents applied by the power supply 9 to the cross-compared elements.

[0166] According to another aspect, which corresponds to the matter previously disclosed with reference to the control mode F5 configuration of figure 6, the method further comprises the following phases:

- detecting an electric parameter selected from the group consisting of the voltage or current in the filament 4;
- adjusting the power supply 9 to apply to the filament 4 a predetermined value of an electric parameter chosen between voltage or current, said chosen electric parameter being different from the electric parameter selected in the previous phase of detecting a parameter selected from the group consisting of the voltage or current in the filament 4;
- check for the presence of a broken connection in the filament 4 based on the detected electric parameter and on the predetermined value of the chosen voltage or current electric parameter applied to the filament 4.

[0167] It is worth noting that the method of the invention provides the same advantages as described previously with regard to the control device 1 of the invention.

[0168] In other words, the method allows for a particularly fast and accurate diagnosis and precise control of the irradiation beam emitting device 2.

[0169] It is further disclosed, according to the invention, the use of a control device 1 according to any of the appended claims for controlling the operational efficiency of an irradiation beam emitting device 2 of a sterilization apparatus 3 for the sterilization of a (preferably packaging) material PM, wherein the irradiation beam emitting device 2 comprises a filament 4 configured to emit, when heated, by thermionic effect, electrons, a second conductor 5 and a first conductor 6 placed inside a vacuum chamber 13.

[0170] According to an aspect, the sensing unit (11) may comprise the third sensor (18), configured to detect a parameter indicative of the voltage or current in the filament (4), and wherein the control unit (10) is further configured for:

- adjusting the power supply (9) to apply to the filament (4) a predetermined value of a parameter chosen between voltage or current, said chosen parameter being different from the parameter detected by the third sensor (18);
- checking if the filament (4) connection is broken based on the parameter detected from the third sensor (18) and on the predetermined value of the voltage or current parameter applied to the filament (4).

[0171] According to an aspect, the sensing unit (11) may comprise the third sensor (18), configured to detect an electric parameter chosen from the group consisting of the voltage or current in the filament (4) and wherein the control unit (10) is further configured for:

- adjusting the power supply (9) to apply to the filament (4), to the second conductor (5) or to the first conductor (6) predetermined relative electrical voltages or currents;
- conducting a cross comparison between a couple of the following cross compared elements: the filament (4), the first conductor (6), the second conductor (5) and a housing (14) enclosing the vacuum chamber (13), to check if a short circuit occurs between any couple of the cross-compared elements, the cross comparison being based on one or more of the detected electric parameter from the first sensor (7), the second sensor (8) or the third sensor (18) and on one or more of the values of electrical voltages or currents applied by the power supply (9) to the cross-compared elements.

[0172] It is known that the irradiation emitting device 2 comprises a cathode, an exit window, a grid and an anode as well as the filament 4. During normal operation, the filament 4 emits electrons which are accelerated towards the exit window thanks to an electromagnetic field generated by applying a voltage to the cathode and the grid. The first conductor 6 may be the cathode. The second conductor 5 may be the grid of the irradiation beam emitting device 2.

[0173] The control device 1 is (directly) connectable to the irradiation beam emitting device 2 for sterilization. In particular, the control device 1 comprises the power supply 9 that is (directly) connectable to the filament 4, to the first conductor 6 and to the second conductor 5 of the irradiation beam emitting device 2 to supply power thereto.

[0174] In other words, the irradiation beam emitting device 2 comprises a power supply port. The power supply port is connected to the filament 4, to the first conductor 6 and to the second conductor 5, e.g. the grid and/or the cathode. During normal operation, a generator is connected to the power supply port to allow power to be fed to the emitting device 2 for emitting the irradiation beam for sterilization.

[0175] The power supply port may be connected (directly) to the power supply 9 of the control device 1. This way, the control device 1 may directly control the operational efficiency of the irradiation beam emitting device 2.

[0176] Advantageously, the components themselves of the emitting device can be used to assess the operational efficiency thereof without a need for external components or sensors, e.g. an ion gauge.

Claims

1. A control device (1) for an irradiation beam emitting device (2), wherein the irradiation beam emitting device (2) is configured to emit an irradiation beam to sterilize an object and comprises a vacuum chamber (13), a filament (4) configured to emit electrons by thermionic effect, when heated, a first electrical conductor (6) and a second electrical conductor (5), said filament (4), first conductor (6) and second conductor (5) being placed inside the vacuum chamber (13),
   the control device (1) comprising:

   - a power supply (9) connectable to the filament (4), to the first conductor (6) and to the second conductor (5) of the irradiation beam emitting device (2) to supply power thereto;
   - a sensing unit (11) comprising at least a first sensor (7) configured to detect at least an electric parameter associated to a current flowing through the first conductor (6), defined as ionization current (IC), and a second sensor (8) configured to detect at least an electric parameter associated to a current flowing through the second conductor (5), defined as an emission current (EC);
   - a control unit (10) coupled to the power supply (9) and to the sensing unit (11) to receive the detected electric parameters therefrom and further configured for actuating a main control mode (F1) of the status of the irradiation beam emitting device (2) comprising:

     - adjusting the power supply (9) to apply on the filament (4) a predetermined current to emit electrons;
     - adjusting the power supply (9) to apply a predetermined voltage on the first conductor (6);
     - adjusting the power supply (9) to apply a predetermined voltage on the second conductor (5); and
     - deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) as a function of the detected electric parameter associated to the ionization current (IC) and of

the detected electric parameter associated to the emission current (EC).

2. The control device (1) according to claim 1, wherein one of the predetermined voltage on the first conductor (6) and the predetermined voltage on the second conductor (5) is positive and the other between the predetermined voltage on the second conductor (5) and the predetermined voltage on the first conductor (6) is negative.

3. The control device (1) according to claims 1 or 2, wherein the control unit (10) is configured for:

- adjusting the power supply (9) to apply on the filament (4), at different time instants, a plurality of predetermined different filament (4) current values, generating a plurality of different electron emissions,
- deriving said status parameter as a function of the detected electric parameter associated to the ionization current (IC) and the detected electric parameter associated to the emission current (EC), taken at the different filament (4) current values.

4. The control device (1) according to any of the previous claims, comprising a memory (12), connected to or integrated in, the control unit (10), for storing at least a reference parameter and wherein the control unit (10) is configured to derive the at least one status parameter representing an operational efficiency of the irradiation beam emitting device (2) as a function of the detected electric parameters associated to the ionization current (IC), of the emission current (EC) and of the at least one reference parameter stored in the memory (12).

5. The control device (1) according to the previous claim, wherein the at least one reference parameter defines a relationship between the ionization current (IC) and the emission current (EC), preferably with respect to a vacuum pressure inside the vacuum chamber (13) of the irradiation beam emitting device (2).

6. The control device (1) according to the previous claims, wherein such at least one reference parameter comprises at least a value defining a mathematical linear relationship between the ionization current (IC) and the emission current (EC) with respect to different vacuum pressures inside the vacuum chamber (13) of the irradiation beam emitting device (2).

7. The control device (1) according to any of the previous claims, wherein the sensing unit (11) comprises a third sensor (18), configured to detect an electric parameter associated to the voltage on the filament (4), and wherein the control unit (10) is further configured for:

- adjusting the power supply (9) to apply to the filament (4) a plurality of different predetermined currents, defined as filament currents (FC);
- deriving at least a filament (4) status parameter, representing the operational efficiency of the filament (4) of the irradiation beam emitting device (2), as function of the detected electric parameter associated to the voltage on the filament (4) and of the filament currents (FC) applied by the power supply (9).

8. The control device (1) according to the previous claim, wherein the control unit (10) is further configured to derive an indication of a vacuum pressure inside the vacuum chamber (13) of the irradiation beam emitting device (2), based on said derived filament (4) status parameter.

9. The control device (1) according to any of the previous claims, wherein the control unit (10) is further configured for:

- adjusting the power supply (9) to apply on the first conductor (6) a predetermined voltage;
- adjusting the power supply (9) to apply on the second conductor (5) a plurality of different predetermined voltages;
- deriving at least a first conductor (6) - second conductor (5) status parameter representing an operational efficiency of the combination of the first conductor (6) and the second conductor (5) as a function of the detected electric parameter associated to the ionization current (IC) and of the detected electric parameter associated to emission current (EC).

10. The control device (1) according to any of the previous claims, wherein the irradiation beam emitting device (2) comprises a cathode and a grid, wherein the first conductor (6) comprises the cathode of the irradiation beam emitting device (2) and/or the second conductor (5) comprises the grid of the irradiation beam emitting device (2) .

11. The control device (1) according to any of the previous claims, wherein the irradiation beam emitting device (2) comprises a power supply port and wherein the power supply (9) of the control device (1) is connectable to the power supply port of the irradiation beam emitting device (2).

12. A sterilization system (100), comprising:

- a sterilization apparatus (3), having at least an

irradiation beam emitting device (2) comprising a vacuum chamber (13), a filament (4) configured to emit electrons by thermionic effect, when heated, a first conductor (6) and a second conductor (5), the filament (4), first conductor (6) and second conductor (5) being placed inside the vacuum chamber (13);
- a control device (1) for controlling the status of said irradiation beam emitting device (2), according to any of the previous claims.

13. A method for controlling the operational efficiency of an irradiation beam emitting device (2), wherein the irradiation beam emitting device (2) comprises a vacuum chamber (13), a filament (4) configured to emit electrons by thermionic effect, when heated, a first conductor (6) and a second conductor (5), said filament (4), first conductor (6) and second conductor (5) being placed inside the vacuum chamber (13), the method comprising:

- adjusting a power supply (9) to apply a predetermined current on the filament (4) to emit electrons, a predetermined voltage on the first conductor (6) and a predetermined voltage on the second conductor (5) defining an electric field between the second conductor (5) and the first conductor (6);
- detecting an electric parameter associated with a current flowing through the first conductor (6), defined as ionization current (IC), and detecting an electric parameter associated with a current flowing through the second conductor (5), defined as emission current (EC);
- deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) as a function of the detected electric parameter associated with the ionization current (IC) and of the detected electric parameter associated with the emission current (EC).

14. The method according to the previous claim, wherein the phase of adjusting the power supply (9) comprises the phase of adjusting the power supply (9) to apply on the filament (4), at different time instants, a plurality of predetermined different current values, generating a plurality of different electron emissions, and wherein the phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) comprises a phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) as a function of the detected electric parameter associated to the ionization current (IC) and of the detected electric parameter associated to emission current (EC) taken at the different filament (4) current values.

15. The method according to the previous claim, wherein the phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) comprises a phase of deriving at least a status parameter representing an operational efficiency of the irradiation beam emitting device (2) as a function of the detected parameters associated with the ionization current (IC), of the emission current (EC) and of at least a reference parameter,
wherein the method further comprises an initial setup phase of calculating said at least one reference parameter which comprises:

- providing at least one test irradiation beam emitting device (2), having a vacuum chamber (13) with an internal vacuum pressure value, the method further comprising the following phases, executed for at least one internal vacuum pressure values:

  - adjusting the power supply (9) to apply a predetermined current on the filament (4) to emit electrons, a predetermined voltage on the first conductor (6) and a predetermined voltage on the second conductor (5);
  - detecting at least an electric parameter associated to a current flowing through the first conductor (6), defined as ionization current (IC), and detecting at least an electric parameter associated to a current flowing through the second conductor (5), defined as the emission current (EC),
  - calculating said at least one reference parameter as a function of said detected electric parameter associated with ionization current (IC) and from said detected electric parameter associated with the emission current (EC);
  - storing said at least one reference parameter, preferably jointly with the internal, vacuum pressure value.

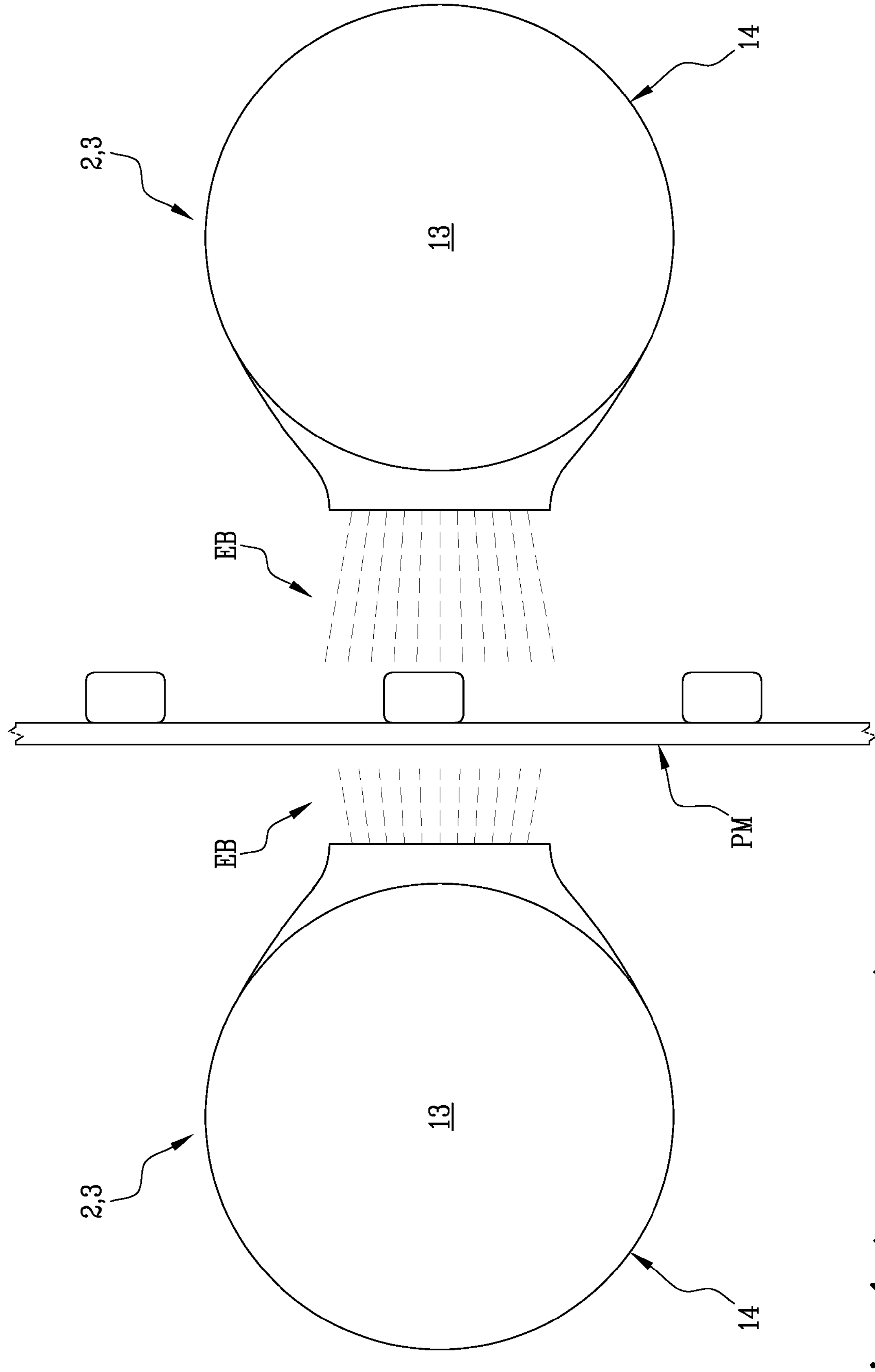


Fig.1 (PRIOR ART)

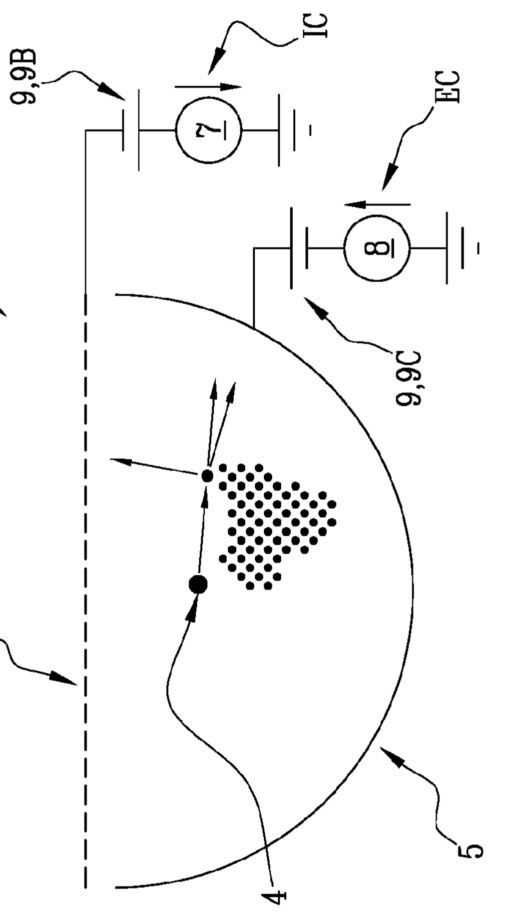


Fig.3

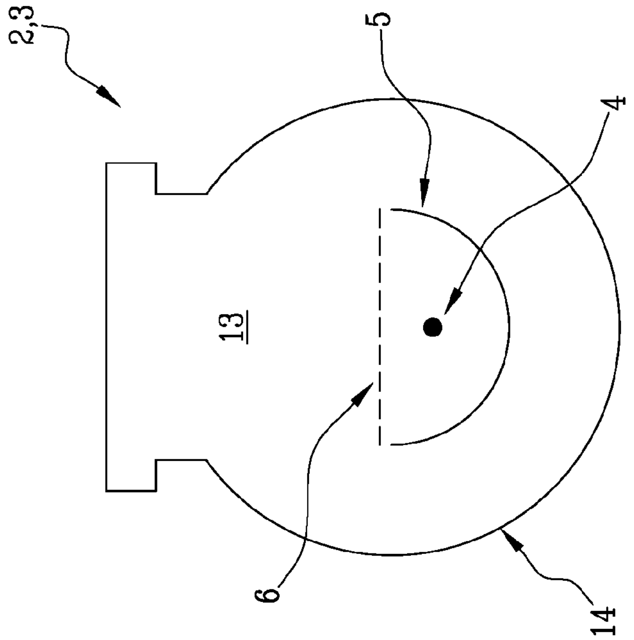


Fig.2

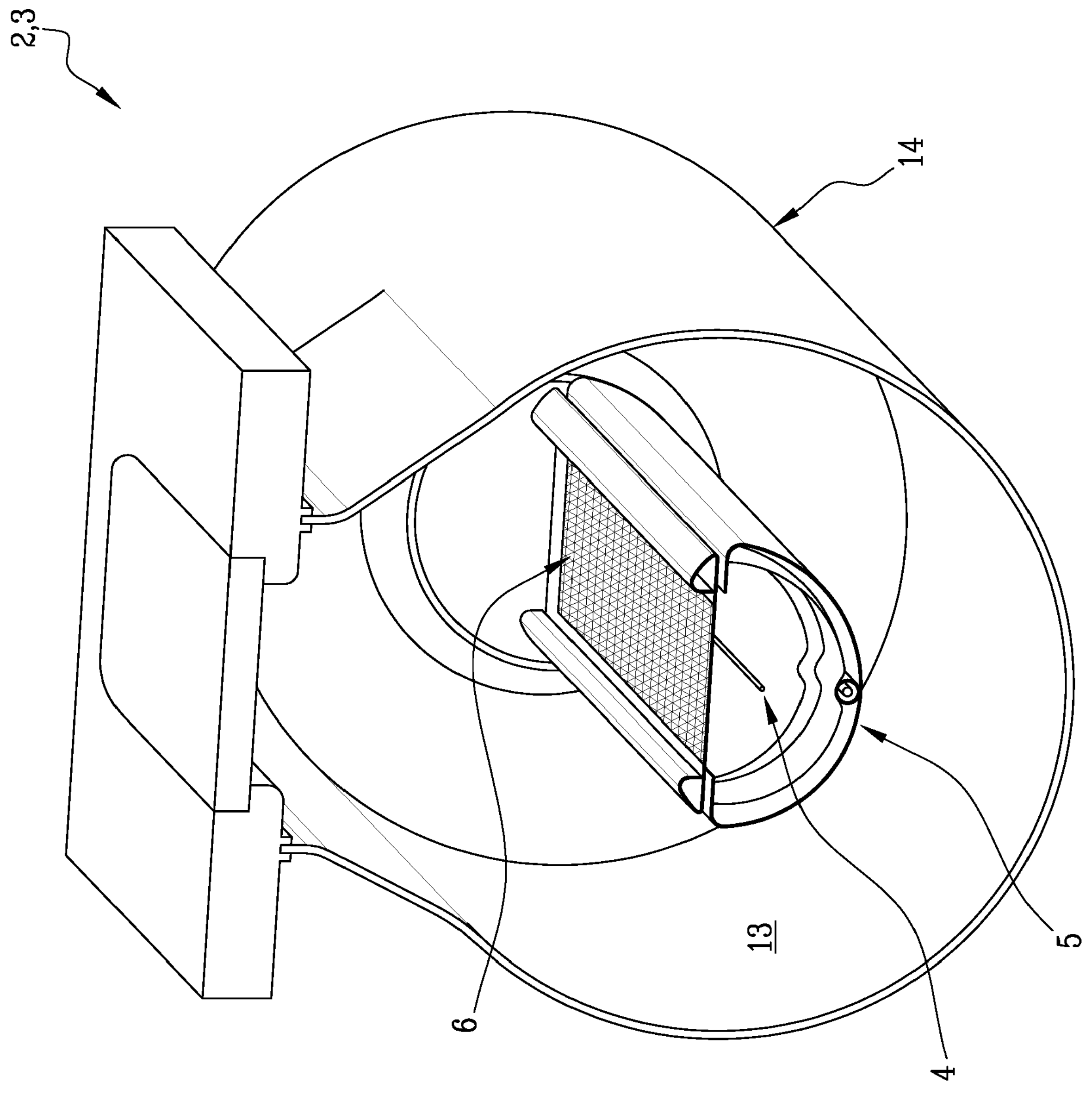
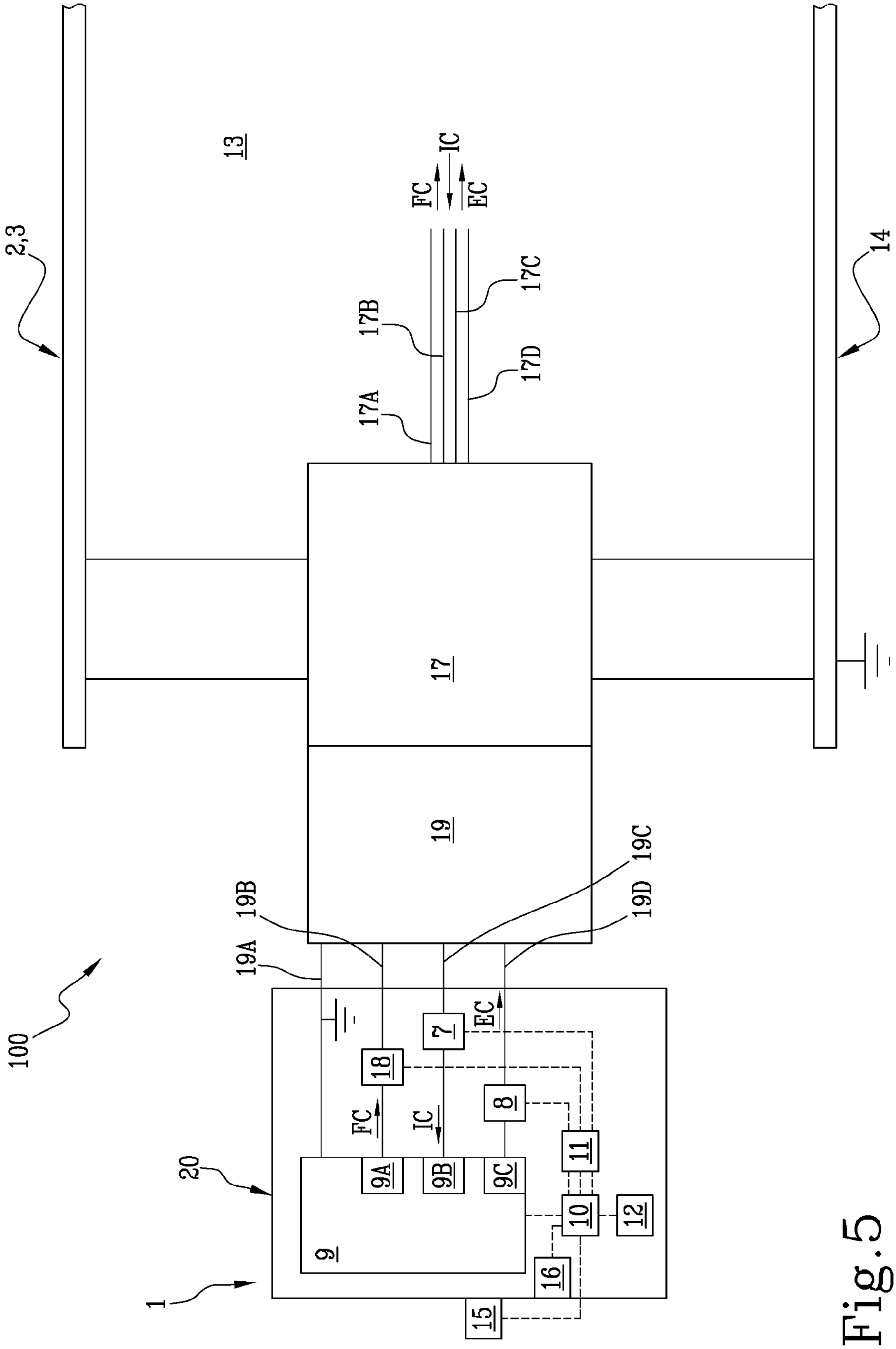


Fig.4


2,3
13
FC
IC
EC
17A
17B
17C
17D
14
17
19
19A
19B
19C
19D
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9C
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10
12
16
15

Fig.5

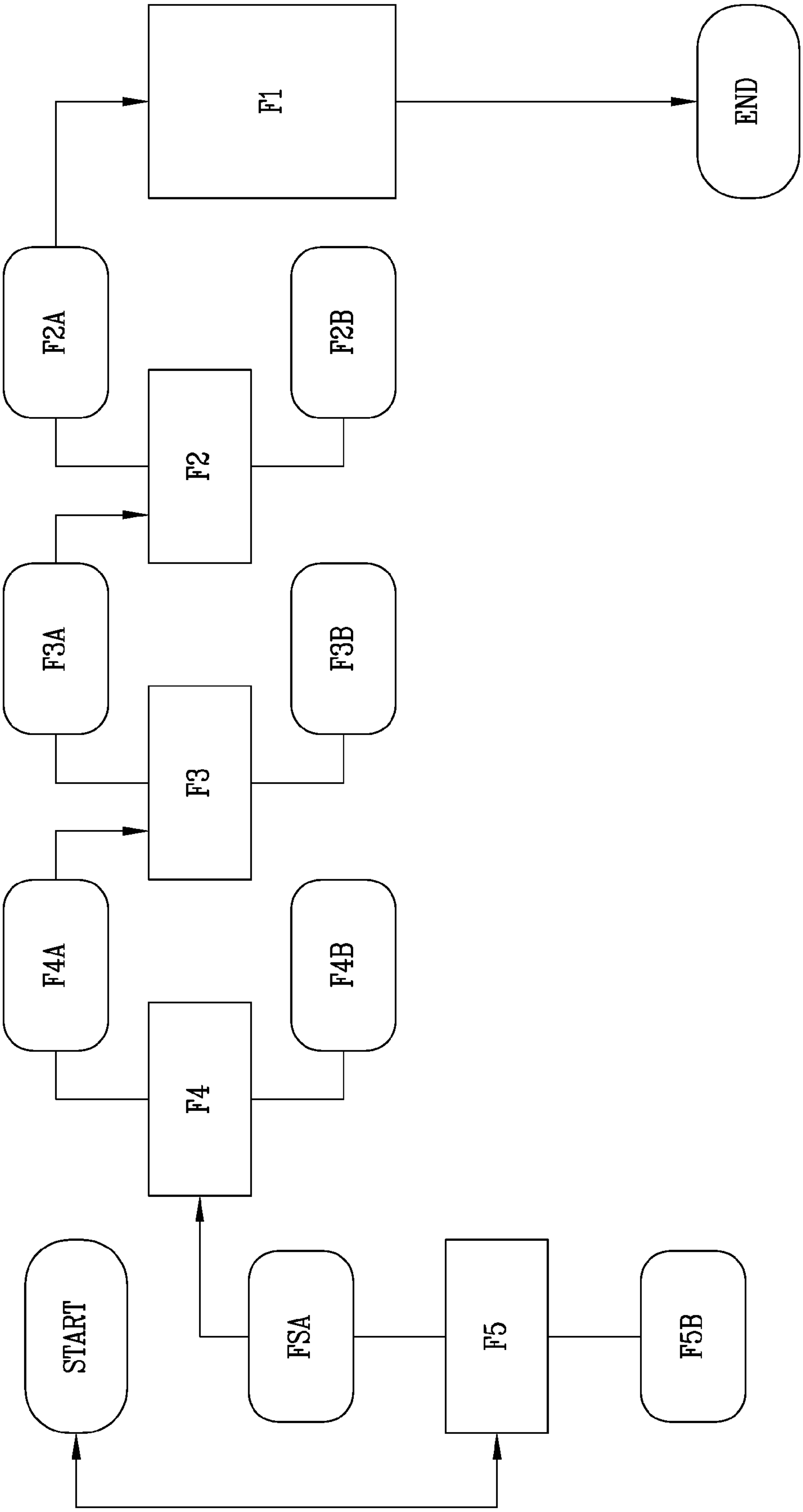

Fig.6

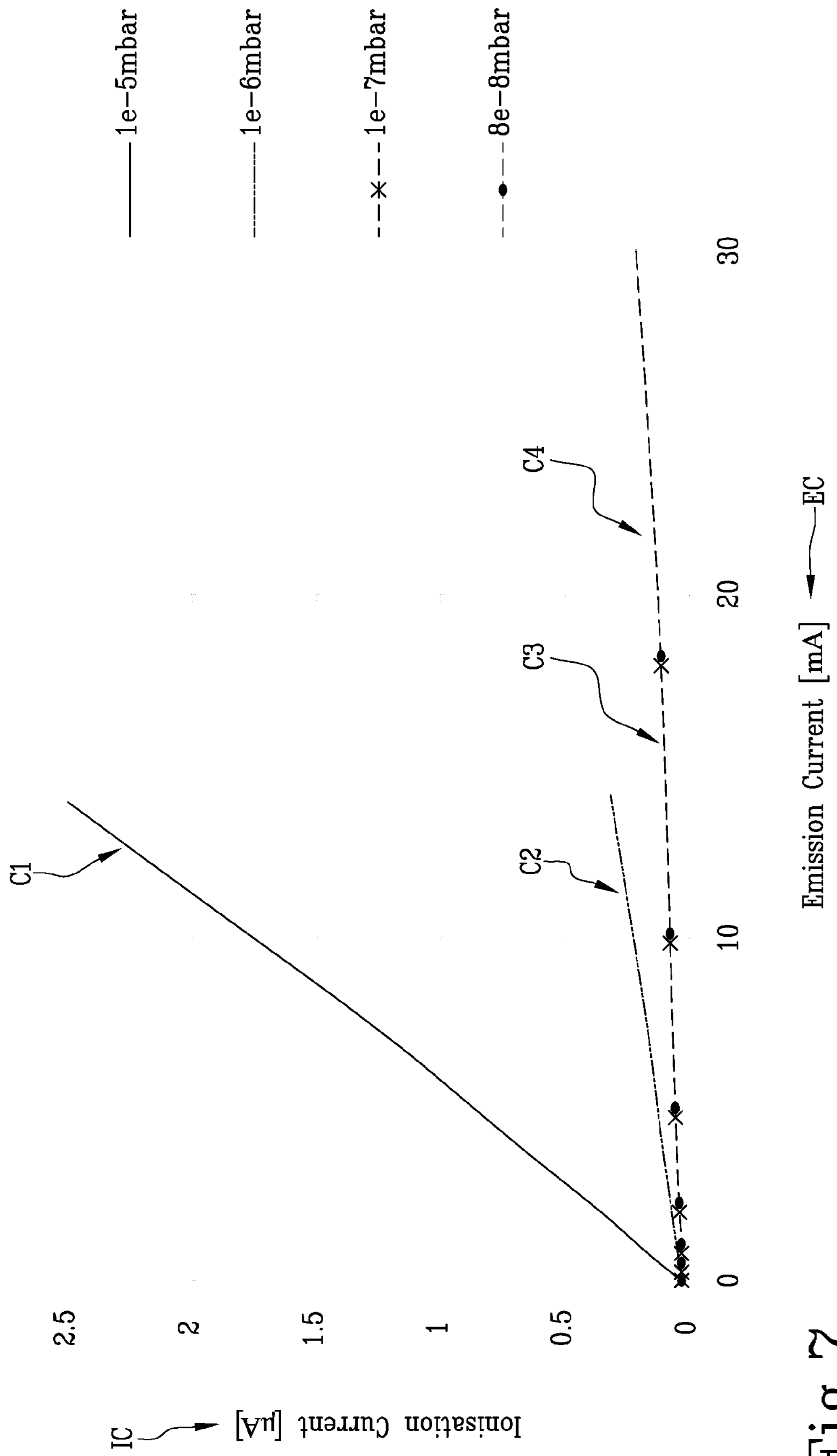
1e-5mbar
1e-6mbar
1e-7mbar
8e-8mbar
C1
C2
C3
C4
2.5
2
1.5
1
0.5
0
0
10
20
30
Ionisation Current [μA]
IC
Emission Current [mA]
EC

Fig.7