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(71) Applicant: **Tantec Holding ApS**
6640 Lunderskov (DK)

(72) Inventor: **Palmelund, Lars**
6600 Vejen (DK)

(74) Representative: **Olesen, Birthe Bjerregaard et al**
Patrade A/S
Fredens Torv 3A
8000 Aarhus C (DK)

(54) AUTOMATIC GAS CONTROL SYSTEM FOR PLASMA TREATMENT

(57) A surface treatment apparatus with automatic gas control system for use in plasma treatment and a method for using a surface treatment apparatus with automatic gas control system for use in plasma treatment.

A surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the apparatus at least includes a controller, a generator, a transformer, a high voltage line, a gas line and a gas regulator, where at least one high voltage line and a gas line are connected to a device that includes at least an electrode and a nozzle, wherein the automatic gas control system at least includes a measuring unit connected to a controller where the controller is connected to an electrically controlled proportional valve or an electrically controlled pressure regulator, by which is achieved an apparatus capable of setting the correct and necessary gas pressure required for producing the correct and/or desired flow in order that the treated items receive a proper and optimal plasma treatment.

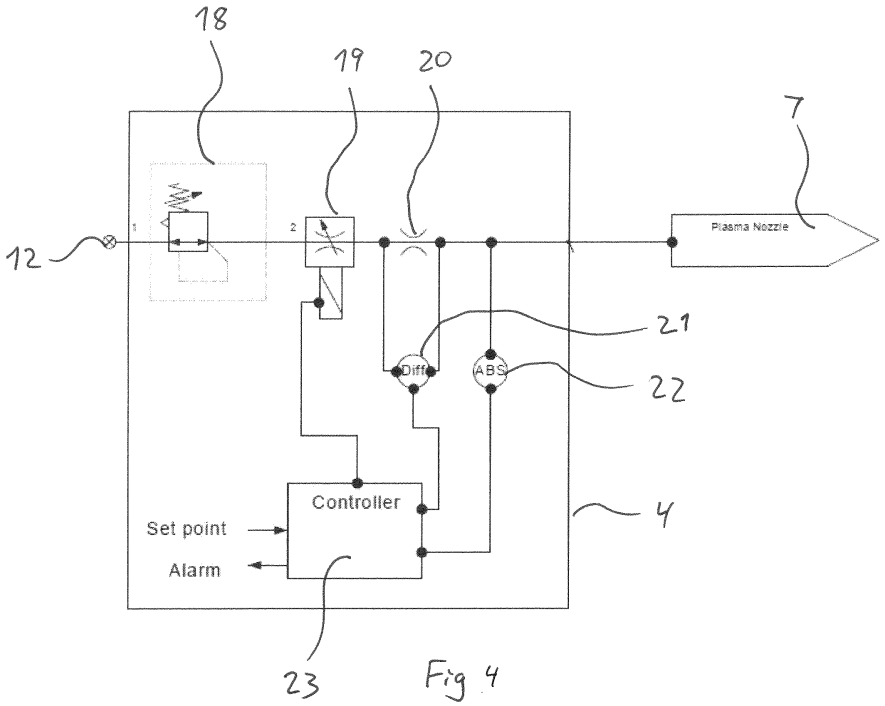

Fig 4

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Description

Field of the Invention

[0001] The present invention concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the apparatus at least includes a controller, a generator, a transformer, a high voltage line, a gas line and a gas regulator, where at least one high voltage line and a gas line are connected to a device that includes at least an electrode and a nozzle.

[0002] The invention also concerns a method for using a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or cleaning the surface of an item.

Background of the Invention

[0003] It is prior art to have surface treatment apparatuses for plasma treatment where high voltage is applied to an electrode, and where the discharge of the electrode is pressed out of the electrode nozzle by means of a pressurised gas for treating the surface of a wide range of items.

[0004] Such a surface treatment apparatus may e.g. be controlled by a microprocessor, microcontroller, CPLD, FPGA or PLC that may control the high voltage of the apparatus and operate a number of nozzles of plasma electrodes whereas a transformer can be equipped with gas pressure monitoring and regulators.

[0005] The purpose of such a treatment is to increase or reduce the surface tension in the treated item, typically from being an item with a low surface tension upon which a test liquid with higher surface tension will lie as droplets to an item with high surface tension upon which a test liquid with lower surface tension will lie as a film on the item. Whether the surface tension is low or high depends on the test liquid in question.

[0006] Another purpose of the treatment can be as part of a cleaning process.

[0007] Plasma is defined as being a gas where at least a large part of the atoms or molecules are transformed into ions by relinquishing or receiving one or more electrons, and where the plasma e.g. consists of a number of negatively charged electrons as well as a number of positively charged ions. The plasma can be formed by heating a gas of neutral particles to such a high temperature that the impacts between the particles become so strong that electrons are expelled from the atoms.

[0008] The plasma is used for the surface treatment in practice by letting the electrons from the discharge of electrons hit the surface of the item, thereby applying the molecules of the items with a force that breaks the molecular bonds and result in a number of open ends in the bonds of the molecular atoms, whereby a number of new chemical bonds can be formed with other atoms from e.g. ozone from the electric discharge, thereby forming a new molecule with higher surface tension.

[0009] By a surface treatment with plasma there is e.g. typically used a current less than 1 A, whereas by cutting with plasma there is typically applied a current of more than 10 A, i.e. a current which is many times greater.

[0010] In practice, the surface treatment apparatus will have earth connection and may thereby act as a counter electrode such that the electrical discharges can take place between the individual electrode and the apparatus.

[0011] One of the drawbacks by the prior art surface treatment apparatuses is that the gas regulation is to be performed manually with the inconveniences and risks associated therewith in the form of the awareness, attention and ability of the worker to set the apparatus correctly, and thereby the associated risk of setting the apparatus incorrectly.

[0012] A further drawback is the risk of an uneven surface treatment of the items.

Object of the Invention

[0013] It is thus the object of the invention to provide a surface treatment apparatus with automatic gas control system for plasma treatment in connection with increasing the surface tension of an item or cleaning the surface of an item, where the apparatus is capable of setting the correct and necessary gas pressure required for producing the correct and/or desired flow by itself in order that the treated items will receive the proper and optimal plasma treatment.

[0014] It is a further object of the invention to provide a surface treatment apparatus which is more efficient and which can perform a suitable and uniform control of the electrodes in connection with plasma treatment and thereby the load on the surface or surfaces to be treated.

Description of the Invention

[0015] According to a first aspect of the invention, the above mentioned object is achieved by a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item as described in the introduction and as indicated by the preamble of claim 1, wherein the automatic gas control system at least includes a measuring unit connected to a controller where the controller is connected to an electrically controlled proportional valve or an electrically controlled pressure regulator.

[0016] The measuring unit enables measurement of e.g. pressure, flow and/or temperature, based on which it is possible to perform automatic regulation of gas.

[0017] In a preferred embodiment, control is performed by a microprocessor, but may alternatively be performed by a microcontroller, CPLD, FPGA or PLC controller that

may control the high voltage of the apparatus for the circuit in the system.

[0018] This will therefore enable performing of automatic gas regulation by which e.g. the gas flow can be interrupted if the signal for the electrically controlled proportional valve or the electrically controlled pressure regulator is removed. Also, it is possible to set the measuring unit to the correct and thus required gas pressure, and consequently the flow required for achieving the proper and optimal plasma treatment.

[0019] Hereby is achieved an apparatus capable of setting the correct and necessary gas pressure required for producing the correct and/or desired flow by itself for the treated items so that they receive a proper and optimal plasma treatment.

[0020] In a second aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the measuring unit at least includes a manometer, a flowmeter or a thermometer. In a third aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the measuring unit at least includes a differential manometer, a mass flowmeter or a thermometer/thermoelement.

[0021] This will enable using a wide range of different pressure, flow and/or temperature gauges, including more specifically a differential manometer, a mass flowmeter or a thermometer/thermoelement.

[0022] As use of at least one meter or gauge is indicated, there may be several separate measuring units, such as a flowmeter and a thermoelement or a unit with a plurality of measuring options, such as a thermal mass flowmeter.

[0023] In a fourth aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the measuring unit at least includes an orifice, a differential manometer and a manometer, or the measuring unit includes an orifice with two manometers.

[0024] By a differential manometer is meant an integrated unit comprising two manometers for measuring differential pressure across the orifice as well as two independent manometers disposed at each their side of the orifice, and where the signals of the manometers are processed in the controller into a differential pressure signal.

[0025] Besides measurement of the differential pressure by using two manometers, the automatic gas control system may additionally have a separate manometer which does not measure the differential pressure but the actual pressure in the system.

[0026] This will therefore enable the performing of automatic gas regulation by which e.g. the gas flow can be interrupted if desired or in case of power failure, entailing that the system can be closed without using additional valves. Also, it is possible to set the correct and thus required gas pressure and thereby the flow required for achieving the proper and optimal plasma treatment.

[0027] In a preferred embodiment is used either e.g. an concentric or eccentric orifice for the differential pressure measurement and where the orifice is adapted to the differential pressure and the permanent pressure drop. Differential manometers generally have the advantage that they are thoroughly tested and one of the most widely used types of meters for continuous measurement, and they are both simple to mount and to maintain, thus ensuring a high degree of stability in operation of the apparatus.

[0028] An alternative for measuring differential pressure may e.g. be vortex meters where the eddy frequency is directly proportional with the velocity of the medium.

[0029] In a fifth aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the automatic gas control system additionally at least includes a constant pressure valve before the electrically controlled proportional valve or the electrically controlled pressure regulator in the direction of flow.

[0030] This will enable securing a constant pressure in the gas control system, something which may be advantageous in case that the gas supply is unstable due to e.g. several other consumers/points of consumption coupled to the same gas supply, which thereby may deliver an unstable and fluctuating gas pressure to the gas control system.

[0031] The constant pressure valve is, however, not necessary in cases/situations where there is a constant supply pressure, i.e. without fluctuations and variations in pressure, but it may be desirable anyway to use a constant pressure valve as an additional safeguard.

[0032] In a sixth aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the apparatus further includes one or more gas regulation systems after the constant pressure valve.

[0033] It is thereby avoided using a constant pressure valve for each single gas regulation system, providing a saving that will not entail any disadvantages as such. Thereby is achieved the possibility of having two or more gas regulation systems in one and the same unit.

[0034] In a seventh aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the controller is an I controller, a PI controller or a PID controller.

[0035] This will enable performing the necessary mathematical transfer functions in order to calculate if the pressure is too high or too low, and in order that a control loop can transmit correcting signals. In a preferred embodiment, only the Proportional Integral (PI) functions are applied.

[0036] In an eighth aspect, the present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the controller includes an alarm function.

[0037] This will enable the triggering of an alarm if the system is not in balance, i.e. if the inlet pressure e.g. is too low. The balance is based on measurement of the pressure at the electrically controlled pressure drop valve and e.g. the pressure across the orifice compared with the pressure at the manometer, where a balance can be achieved e.g. after 200 ms. By the alarm is avoided continuation of the plasma treatment of items where the plasma treatment thus is not optimal. An alarm function therefore results in subsequent trouble-shooting and fixing/correcting of the fault before operation can be normal again.

[0038] The present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the controller includes a predetermined setpoint.

[0039] This will enable determination of the setpoint in advance, depending on choice of nozzle, desire and need, where the setpoint e.g. can be adjusted according to the choice of material to be plasma treated. An example of a setpoint can be 2.2 m^3/hr for a round nozzle.

[0040] The present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the apparatus includes at least one internal power supply/high voltage generator.

[0041] This will enable integration of one or more power supplies/high voltage generators in the unit whereby the unit becomes more compact, as alternative to an external power supply/high voltage generator which will complicate mounting, handling and connection to the unit.

[0042] The present invention also concerns a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the apparatus includes a multi-function plug connection, the plug connection comprising current, earthing as well as gas.

[0043] This will enable connecting a high voltage line, an earth connection and a gas line to a device including at least one electrode and a nozzle. By the multi-function plug connection is thus achieved the possibility and advantage of replacing one connection with a different and either shorter or longer connection with e.g. the purpose of getting the nozzle up to the wanted point of treatment, and at the same time maintaining the flow in the nozzle point, or just replacing and repairing a connection.

[0044] In a ninth aspect, the present invention concerns also a method for using a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or cleaning the surface of an item according to claims 1 to 8, wherein the gas is automatically regulated by the following steps:

a) opening for the gas which is fed to the system by a feed pressure;
b) an electrically controlled proportional valve or an electrically controlled pressure regulator is closed;
c) the electrically controlled proportional valve or the electrically controlled pressure regulator is opened;
d) the gas passes the electrically controlled proportional valve or the electrically controlled pressure regulator;
e) the gas passes a measuring unit;
f) the result of the measurements is transmitted to a control unit which calculates if the pressure is to high or too low, based on a defined set point and a control loop with a mathematical transfer function;
g) the control unit sends a regulating signal to the electrically controlled proportional valve or the electrically controlled pressure regulator;
h) go to item e.

[0045] This will enable supplying the gas to the system at a pressure of preferably 4-8 bar, after which the controller calculates a balance based on the mathematical transfer function of the control loop as a result of e.g. the differential pressure and the actual pressure, causing the achievement of correct pressure/flow at the nozzle.

[0046] By the last step in the method is ensured a repetition of a series of steps and thereby an automatic regulation of the gas.

[0047] Moreover, it has the advantage that the more the electrically controlled pressure drop valve is opened the greater the pressure drop across e.g. the orifice becomes, and the greater the flow will be in the system.

[0048] In a tenth aspect, the present invention also concerns a method for using a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or cleaning the surface of an item according to claim 9, wherein the method further includes the following regulating step after step g) and before step h):

g') if the pressure is too high, the control unit sends a signal to the electrically controlled proportional valve or the electrically controlled pressure regulator for lowering the pressure, and if the pressure is too low, the control unit sends a signal to the electrically

controlled proportional valve or the electrically controlled pressure regulator for elevating the pressure.

[0049] This will enable automatic adjusting of the gas and thereby the flow in the gas regulation system without manual operation, whereby the risk of any errors is eliminated.

Description of the Drawing

[0050] The invention will now be explained more closely in the following by description of non-limiting embodiments with reference to the drawing, where:

Fig. 1 shows an example of prior art;
Fig. 2 shows a gas diagram according to the prior art;
Fig. 3 shows a general gas diagram according to the invention;
Fig. 4 shows a gas diagram according to the invention.

List of designations

[0051]

1	surface treatment apparatus
2	high voltage generator
3	transformer
4	unit
5	high voltage line
6	gas line
7	device
8	nozzle
9	electrode
10	manual gas regulation
11	gas regulation screw
12	gas inlet
13	manually regulated constant pressure valve
14	manometer
15	pressure monitoring sensor
16	switch/contact
17	manually adjustable regulating valve
18	manually regulated constant pressure valve
19	electrically controlled proportional valve/pressure regulator
20	orifice
21	differential manometer
22	manometer
23	controller
24	measuring unit

Detailed Description of Embodiments of the Invention

[0052] Fig. 1 shows an example of the prior art of a surface treatment apparatus 1 for use in plasma treatment where the apparatus 1 includes a high voltage generator 2 and a transformer 3 incorporated in a unit 4 from which high voltage lines 5 and gas lines 6 together with an earth connection are connected to a device 7 that includes a nozzle 8 and an electrode 9.

[0053] The unit 4 additionally has a manual gas regulator 10 which is common to both devices 7, and the unit 4 also has gas regulation screws 11 for the individual device.

[0054] Fig. 2 shows a gas diagram of the prior art where the unit 4 includes a gas regulating system with gas inlet 12 and a manually regulated constant pressure valve 13, here shown with a manometer 14, which is regulated by means of the manual gas regulator 10.

[0055] After passage of the gas through the constant pressure valve 13, a pressure monitoring sensor 15 is passed which by means of a switch/contact 16 is capable of shutting off the system in case of pressure drop.

[0056] The further course of the gas occurs through a manually adjustable regulating valve 17 before the gas reaches the device 7.

[0057] Fig. 3 shows in general an automatic gas regulation system with gas inlet 12 where the gas flows through an electrically controlled proportional valve/pressure regulator 19, a measuring unit 24 to the device 7. The measuring unit 24 transmits the result of the measurements to the controller 23 which transmits a regulating signal to the electrically controlled proportional valve/pressure regulator 19.

[0058] Fig. 4 shows a gas diagram in an embodiment according to the invention, where the unit 4, apart from the gas regulation system, also contains high voltage generator 2 and transformer 3 (not shown on the diagram).

[0059] Fig. 4 shows an automatic gas control system with gas inlet 12, and where the gas in a preferred embodiment can but not necessarily has to pass a manually regulated constant pressure valve 18. The constant pressure valve 18 may alternatively be automatic.

[0060] The further course of the gas is through an electrically controlled proportional valve/pressure regulator 19, an orifice 20 and a differential manometer 21, and a manometer 22, where the differential manometer 21 measures the differential pressure across the orifice 20.

[0061] The gas passes the manometer 22 measuring the pressure, and the result of the measurements of the differential pressure and the pressure measurement is then transmitted to a controller (regulator) 23 which, based on a defined setpoint and a control loop with mathematical transfer function, calculates whether the pressure is too high or too low, causing the controller 23 to transmit a regulating signal to the electrically controlled proportional valve/pressure regulator 19.

[0062] After passage of the manometer 22, the gas reaches the device 7.

Claims

1. A surface treatment apparatus with automatic gas

control system for use in plasma treatment in connection with increasing the surface tension of an item or for cleaning the surface of an item, wherein the apparatus at least includes a controller, a generator, a transformer, a high voltage line, a gas line and a gas regulator, where at least one high voltage line and a gas line are connected to a device that includes at least an electrode and a nozzle, **characterised in that** the automatic gas control system at least includes a measuring unit connected to a controller, where the controller is connected to an electrically controlled proportional valve or an electrically controlled pressure regulator.

2. Surface treatment apparatus according to claim 1, **characterised in that** the measuring unit at least includes a manometer, a flowmeter or a thermometer.

3. Surface treatment apparatus according to any of claims 1 and 2, **characterised in that** the measuring unit at least includes a differential manometer, a mass flowmeter or a thermometer/thermal element.

4. Surface treatment apparatus according to any of claims 1 to 3, **characterised in that** the measuring unit at least includes an orifice, a differential manometer and a manometer or the measuring unit includes an orifice with two manometers.

5. Surface treatment apparatus according to any of claims 1 to 4, **characterised in that** the automatic gas control system additionally at least includes a constant pressure valve before the electrically controlled proportional valve or the electrically controlled pressure regulator in the direction of flow.

6. Surface treatment apparatus according to claim 5, **characterised in that** the apparatus further includes one or more gas regulation systems after the constant pressure valve.

7. Surface treatment apparatus according to any of claims 1 to 6, **characterised in that** the controller is an I controller, a PI controller or a PID controller.

8. Surface treatment apparatus according to any of claims 1 to 7, **characterised in that** the controller includes an alarm function.

9. A method for using a surface treatment apparatus with automatic gas control system for use in plasma treatment in connection with increasing the surface tension of an item or cleaning the surface of an item according to claims 1 to 8, **characterised in that** the gas is regulated automatically by the following steps:

a. opening for the gas which is fed to the system by a feed pressure;
b. an electrically controlled proportional valve or an electrically controlled pressure regulator is closed;
c. the electrically controlled proportional valve or the electrically controlled pressure regulator is opened;
d. the gas passes the electrically controlled proportional valve or the electrically controlled pressure regulator;
e. the gas passes a measuring unit;
f. the result of the measurements is transmitted to a control unit which calculates if the pressure is to high or too low, based on a defined set point and a control loop with a mathematical transfer function;
g. the control unit sends a regulating signal to the electrically controlled proportional valve or the electrically controlled pressure regulator;
h. go to item e.

10. Method according to claim 9, **characterised in that** the method further includes the following regulating steps after step g. and before step h.:

g'. if the pressure is too high, the control unit sends a signal to the electrically controlled proportional valve or the electrically controlled pressure regulator for lowering the pressure, and if the pressure is too low, the control unit sends a signal to the electrically controlled proportional valve or the electrically controlled pressure regulator for elevating the pressure.

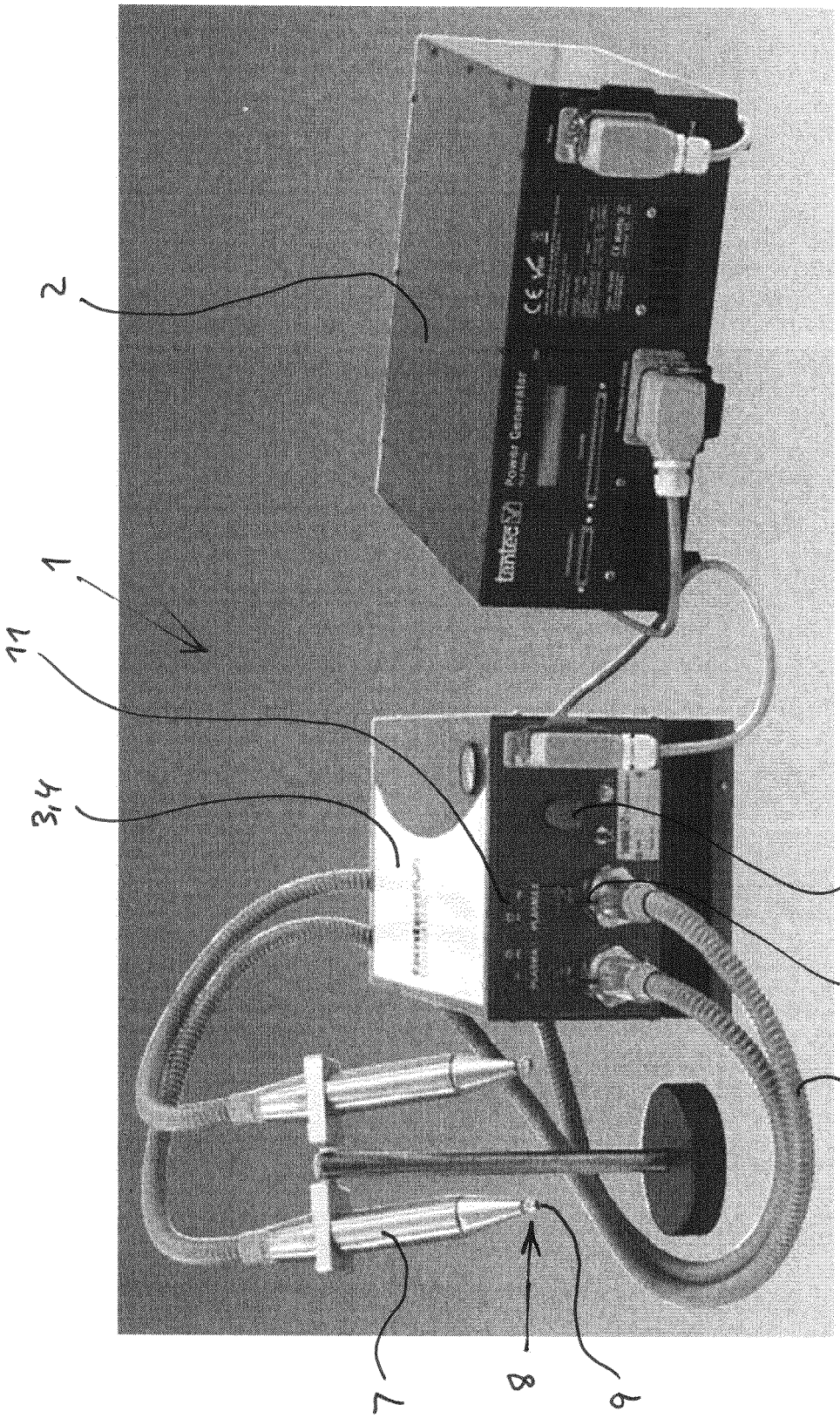

Fig1

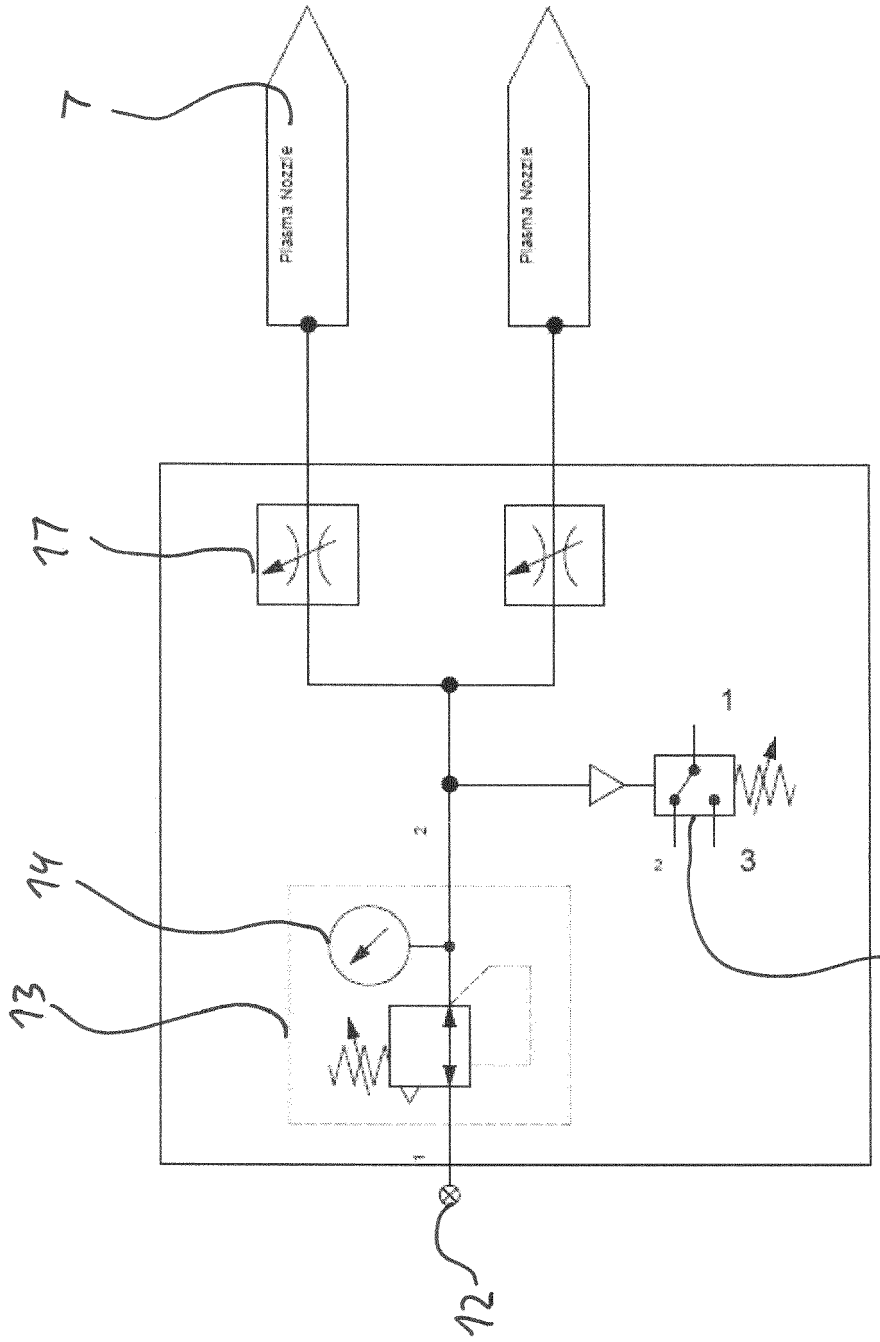

Fig 2

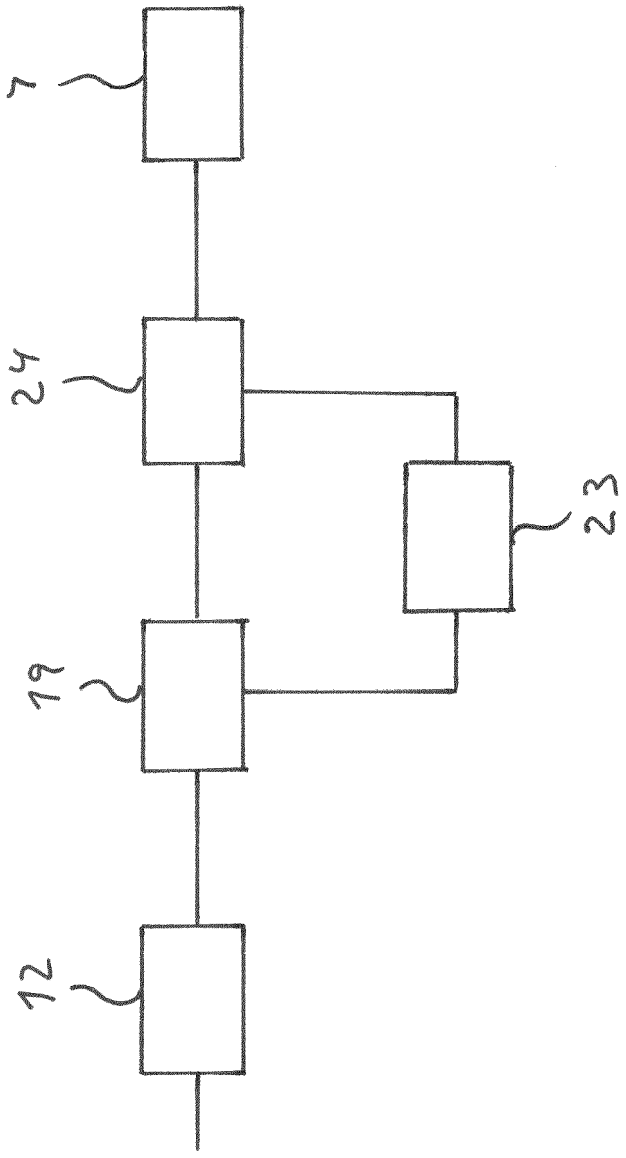

Fig 3

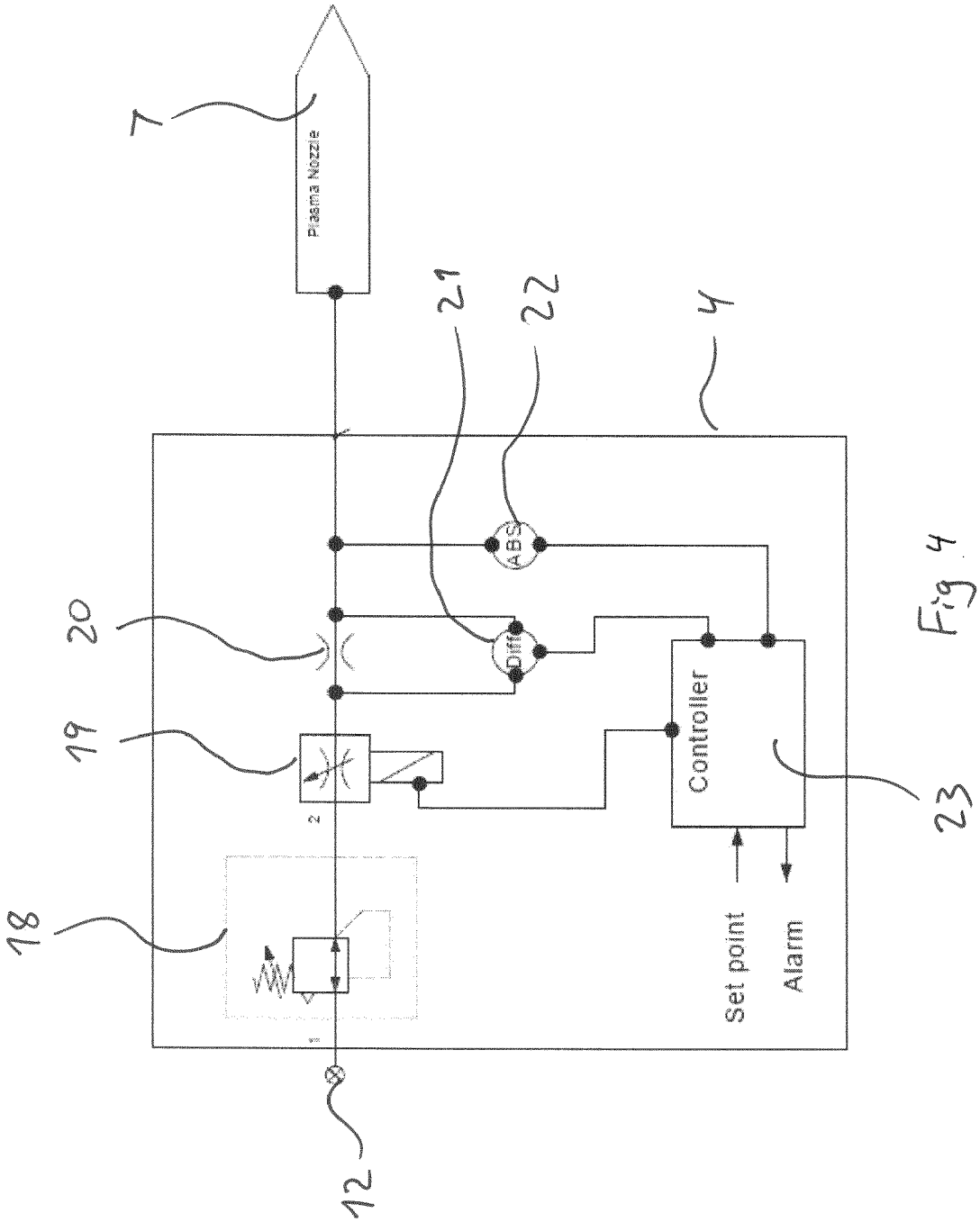
7
Plasma Nozzle
21
22
4
ABS
Diff
20
19
18
12
Controller
23
Set point
Alarm

Fig 4

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EUROPEAN SEARCH REPORT

Application Number
EP 16 15 0546

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	19 May 2016	de Ruijter-Noordman

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 16 15 0546

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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