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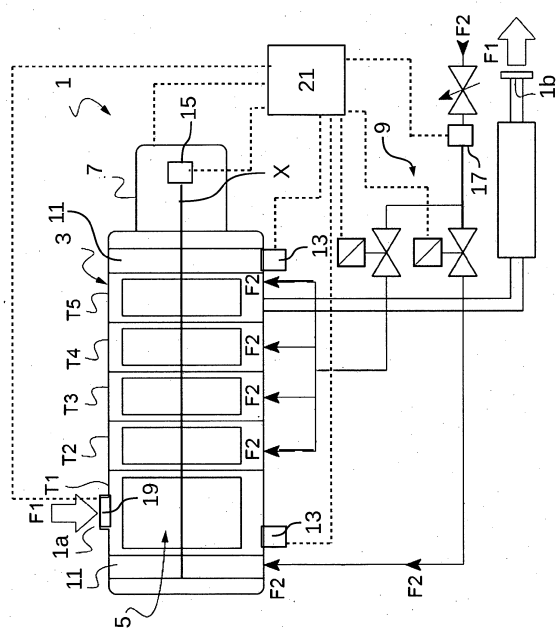
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(54) **VACUUM PUMP AND VACUUM SYSTEM**

(57) The present invention refers to a vacuum pump (1) comprising:  
- a plurality of sensors (11, 13, 15, 17, 19) configured for measuring parameters associated with a state of the vacuum pump (1),  
- a control unit (21) configured for retrieving measurements from the sensors (11, 13, 15, 17, 19) and for determining recursively over time an operating point of the vacuum pump (1) based on one side on the retrieved

measurements and on the other side on an operating mode of the vacuum pump (1) selected by a user among a plurality of operating modes and for applying the determined operating point.

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**Fig.1**

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## Description

### TECHNICAL FIELD

**[0001]** The present invention relates to the field of vacuum equipment configured for putting under vacuum a processing chamber, for example for the semi-conductor manufacturing.

### BACKGROUND OF THE INVENTION

**[0002]** Depending on the application, vacuum equipments and notably vacuum pumps may be solicited in different manners. Indeed, some applications require repeated fast decreases of pressure in a vacuum chamber in order to optimize the number of processed pieces, for example semi-conductors, within a given time lapse while other applications do not require such fast decrease in pressure and therefore may apply less constraints to the vacuum pump. Thus, if the settings of the vacuum pump are set during manufacturing and are not adjusted depending on the requirements of the user, the vacuum pump will either produce a sub-optimal yield for users looking for high performance (fast decrease of pressure) or will lead to a poor lifetime or higher operation costs for users who are not looking for such high performances. Furthermore, many parameters of a vacuum equipment may influence its state and have to be taken into account to determine an optimal operating point. However, these parameters may have cross-correlation so that the determination of the optimal operating point may be particularly difficult to determine for complex vacuum equipments.

### SUMMARY OF THE INVENTION

**[0003]** It is therefore a goal of the present invention to provide a solution enabling a permanent adaptation of the vacuum equipment settings to provide an operating point corresponding to the user requirements.

**[0004]** Thus, the present invention refers to a vacuum pump comprising:

- a plurality of sensors configured for measuring parameters associated with a state of the vacuum pump,
- a control unit configured for retrieving measurements from the sensors and for determining recursively over time an operating point of the vacuum pump based on one side on the retrieved measurements and on the other side on an operating mode of the vacuum pump selected by a user among a plurality of operating modes and for applying the determined operating point.

**[0005]** Such recursive determination and application of an operating point over time based on measurements and on a selected mode enables optimizing the operating

point according to the user requirements and therefore to adapt the control of the vacuum pump to a particular application without requiring time-consuming and cumbersome configurations of the vacuum pump during its manufacturing to adapt the configuration of the vacuum pump to the customer requirements.

**[0006]** According to another aspect of the invention, at least some of the parameters associated with a state of the vacuum pump are cross-correlated parameters.

**[0007]** According to another aspect of the invention, the plurality of operating modes refers to operating modes among the following list:

- a mode configured for optimizing a performance of the vacuum pump,
- a mode configured for maximizing a lifetime of the vacuum pump,
- a mode configured for limiting a functioning cost of the pump,
- a mode configured for limiting energy and/or resources consumption.

**[0008]** According to another aspect of the invention, the control unit is configured to apply a fuzzy logic on the retrieved measurements to determine the operating point of the vacuum pump.

**[0009]** According to another aspect of the invention, the control unit comprises a neural network configured for determining the operating point of the vacuum pump based on the retrieved measurements.

**[0010]** According to another aspect of the invention, the parameters associated with a state of the vacuum pump are chosen among the following list:

- a temperature of the vacuum pump,
- a rotational speed of a rotor of the vacuum pump,
- a flow rate of a cooling fluid,
- a purge gas flow,
- a pressure level at an input of the vacuum pump or in a chamber coupled to the vacuum pump,
- a valve setting,
- vibrations of a part of the vacuum pump
- intensity of a motor of the vacuum pump,
- a noise level of the vacuum pump,
- ultrasonic from the vacuum pump.

**[0011]** According to another aspect of the invention, the application of the determined operating point comprises a control of a supply current controlling the rotational speed of the rotor and a control of a flow rate of a cooling fluid.

**[0012]** According to another aspect of the invention, the control unit is configured to take into account current and past retrieved measurements for determining the operating point of the vacuum pump.

**[0013]** According to another aspect of the invention, the control unit is configured for assessing a remaining useful lifetime of the vacuum pump or parts of the vacuum

pump according the operating points applied over time and for emitting a warning signal when the determined remaining useful lifetime is below a predetermined threshold.

**[0014]** The present invention also refers to a vacuum system comprising a vacuum chamber, at least a vacuum pump and a plurality of sensors configured for measuring parameters associated with a state of the vacuum system and a control unit configured for retrieving measurements from the sensors and for determining recursively over time an operating point of the vacuum system based on one side on the retrieved measurements and on the other side on an operating mode of the vacuum system selected by a user among a plurality of operating modes and for applying the determined operating point.

**[0015]** According to another aspect of the invention, the sensors refer to pressure sensors located in different parts of the vacuum system, temperature sensors located in different parts of the vacuum system, a sensor configured for measuring the rotational speed of a rotor of the at least one vacuum pump, a sensor configured for measuring a setting of the at least one valve.

**[0016]** According to another aspect of the invention, the control unit comprises a neural network configured for determining the operating point of the vacuum system based on the retrieved measurements.

**[0017]** According to another aspect of the invention, the neural network is configured to produce an adaptation of the operating point over time according to previous states of the vacuum system.

**[0018]** According to another aspect of the invention, the neural network is configured to determine a position and a function of different components of the vacuum system based on past measurements and past states of the vacuum system and wherein the neural network is configured to adapt the operating point of the vacuum system when a new component is introduced in the vacuum system.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0019]**

FIG.1 is a diagram of a vacuum pump according to the present invention;

FIG.2 is a diagram of an example of a definition of fuzzy logic qualifiers associated with a rotor temperature;

FIG.3 is a diagram of a vacuum system according to the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

**[0020]** The following achievements are examples. Although, the specification refers to one or several embodiments, it does not imply that each reference refers to the same embodiment or that the features apply only to a single embodiment. Simple features of different embod-

iments can also be combined to provide other embodiments.

**[0021]** The present invention refers to vacuum equipments configured for putting under vacuum a vacuum chamber which is generally a processing chamber. The vacuum equipments refer in particular to a vacuum pump or a vacuum system comprising one or several vacuum pump(s) and additional parts associated with the vacuum pump(s). In the following of the description, the embodiments or features may be described based on a vacuum pump or a vacuum system but the functioning may be adapted to any vacuum equipments.

**[0022]** Fig.1 represents a diagram of an example of a vacuum pump 1. The vacuum pump 1 may be a primary pump such as a dry pump configured to have its output 1b evacuating at an atmospheric pressure as represented in Fig.1. Alternatively, the invention may be applied on a turbomolecular pump configured to be coupled with a primary pump or any other types of vacuum pumps known by the man skilled in the art.

**[0023]** In the case represented in Fig.1, the vacuum pump 1 comprises an input 1a configured to be coupled to a vacuum chamber where the vacuum needs to be set. The vacuum pump 1 comprises a stator 3 inside which two rotors 5 (in Fig.1, the second rotor is hidden by the first rotor) rotating around two parallel axis X and defining a plurality of pumping stages, five in the present case, noted T1, T2, T3, T4 and T5. The rotors 5 are configured for drawing in the gas noted F1 at the input 1a, compress the said gas F1 and expel it toward an output 1b of the vacuum pump 1. The vacuum pump 1 also comprises an electric motor 7 configured for rotating the rotors 5. The pumping stages T1...T5 are coupled in series so that the gas F1 is transmitted through the different stages T1...T5.

**[0024]** The vacuum pump 1 also comprises an injection purge gas device 9 comprising at least one duct configured to be coupled to a purge gas supply. The purge gas is noted F2. In the present case, the injection purge gas device 9 comprises several ducts coupled to the different stages T1...T5 of the vacuum pump 1. One of the duct is also coupled to a bearing 11. The injection of purge gas F2 enables protecting the different parts of the vacuum pump 1 in contact with the pumped gas F1 which may be aggressive and may damage the vacuum pump 1. The vacuum pump 1 may also comprise a hydraulic circuit (not represented) configured for circulating a cooling fluid in the stator 3, for example next to the rotors 5, or next to the bearings 11.

**[0025]** The vacuum pump 1 also comprises a plurality of sensors configured for measuring parameters associated with a state of the vacuum pump 1, these parameters may have cross-correlation. The sensors may be sensors from the following list:

- temperature sensors. 13 which can be arranged in different part of the vacuum pump 1 such as next to the different pumping stages, next to the bearings 11,

- rotational speed sensors 15 configured for measuring a rotational speed of the rotors 5 of the vacuum pump 1,
- flow rate sensors 17 configured for measuring flow rates of a purge gas,
- flowmeters configured for measuring a flow of cooling fluid,
- pressure sensors 19 which can be arranged in different part of the vacuum pump such as the input 1a or the output 1b of the vacuum pump 1 or in a vacuum chamber coupled to the input of the vacuum pump 1,
- valve setting sensors configured for transmitting different signals according to the valve settings, for example valves configured to control the flow of cooling fluid,
- vibrations sensors such as accelerometers arranged on a part, such as the stator 3, of the vacuum pump 1,
- magnetic field sensors configured for controlling electromagnetic bearings of the vacuum pump 1,
- current sensor to measure the intensity of the current supplied to a motor of the vacuum pump,
- acoustic sensors for measuring a noise level associated with the vacuum pump,
- ultrasonic sensor for measuring ultrasonic produced by the vacuum pump.

**[0026]** The vacuum pump 1 also comprises a control unit 21 configured for retrieving measurements from the plurality of sensors mentioned previously. The control unit 21 is also configured for determining an operating point of the vacuum pump 1 based on one side on the retrieved measurements and on the other side on an operating mode of the vacuum pump 1 selected by a user. A plurality of operating modes may be predefined during manufacturing of the vacuum pump 1. One of the predefined modes is selected by the user according to its application. The different operating modes refer for example to one of the following operating modes:

- a performance mode wherein the vacuum pump is configured to obtain the target pressure at the input of the vacuum pump or in a vacuum chamber coupled to the input of the vacuum pump as fast as possible,
- a lifetime enhancement mode wherein the vacuum pump is configured to limit its performance when a possible damaging level of a parameter is reached such as a temperature threshold of the rotors,
- a cost limiting mode configured to minimize the functioning costs of the vacuum pump wherein the vacuum pump is controlled to limit the energy consumption and the resources, such as the amount of purge gas, consumption.
- an average mode configured to provide higher performances than the lifetime enhancement mode while providing a higher lifetime than the performance mode.

**[0027]** Any other modes that could be interesting for a user may also be predefined.

**[0028]** The control unit 21 is also configured for applying the determined operating point, for example by controlling the rotational speed of the rotors 5 via the electric motor 7, by setting the different valves or by controlling the purge gas flow rate or the cooling fluid flow rate. Such determination and application of the operating point are achieved recursively over time, for example with a given frequency. The frequency may be chosen according to the capacity of the different components and may be a few Hz. Such recursive determination over time enable an adaptation of the operating point according to the evolution of the different measured parameters and therefore an optimization of the control of the vacuum pump 1. According to a first embodiment, the control unit 21 is configured to apply fuzzy logic commands to determine the operating point.

**[0029]** The fuzzy logic commands refer to the application of predefined rules that depend on the values of the measured parameters with respect to predetermined thresholds associated with different states of the vacuum pump 1. Furthermore, the different thresholds may refer to ranges of values that can overlap with each other so that the transition between two states of the vacuum pump 1 may be progressive.

**[0030]** Fig.2 represents an example of fuzzy logic rules associated with a rotor temperature. In Fig.2, the abscissa refers to a rotor 5 temperature and the ordinate refers to the memberships to set, that is to say the qualifiers or variables associated to different ranges of temperature. In the present case, five qualifiers are used to cover the whole range of temperature of the rotor 5 but any numbers of qualifiers may be used depending on the required accuracy. The different qualifiers refer respectively to a cold state below 30°C, a cool state around 45°C, a moderate state around 60°C, a warm state around 75°C and a hot state above 90°C. As can be seen in Fig.2, a given state overlaps with the adjacent states.

**[0031]** In the same way, the different parameters determining the state of the vacuum pump 1 may be mapped with qualifiers. The number of qualifiers may be different for the different parameters. Thus, different rulesets may be defined for the different operating modes and the rulesets associated with the chosen mode may be applied to control the vacuum pump 1.

**[0032]** For example, considering a vacuum pump 1 with parameters associated with the rotor 5 speed, the rotor 5 temperature and the pressure in the vacuum chamber connected upstream of the vacuum pump 1. The values of these parameters are given by respective sensors and are mapped with low, nominal and high variables. This example has a limited number of parameters and a limited number of qualifiers for each parameter to remain simple but in practice, other parameters of the vacuum pump 1 may also be taken into account as indicated by the list of sensors described above. A primary goal of a ruleset may be to meet the desired temperature

or to fall below it. A secondary goal may be to save energy and reduce wear by lowering the rotor speed if possible. However, if the rotor is cool, a boost mode can be used to improve the performance and reduce the time required until the vacuum chamber is sufficiently evacuated.

**[0033]** A first possible ruleset associated with a normal mode may be as follow:

if pressure is high and rotor temperature is low, set rotor speed to high,  
if pressure is high and rotor temperature is high, set rotor speed to nominal,  
if pressure is nominal, set rotor speed to nominal,  
if pressure is low, set rotor speed to low.

**[0034]** A second possible ruleset associated with a performance mode may be as follow:

if pressure is high and rotor temperature is low, set rotor speed to high,  
if pressure is high and rotor temperature is high, set rotor speed to high,  
if pressure is nominal, set rotor speed to nominal,  
if pressure is low, set rotor speed to low.

**[0035]** Thus, the operating point is determined by the control unit 21 based on the sensors measurements and the ruleset of the selected operating mode. The control unit 21 is then configured to apply the determined operating point. The application of the determined operating point refers for example to the control of a supply current controlling the rotational speed of the rotor 5. Such application may also refer to the control of a flow rate of a cooling fluid or to the control of any other controlling parameters of the vacuum pump 1. The application of a fuzzy logic enables controlling efficiently the vacuum pump to reach an optimal operating point without requiring important processing means to take into account the cross-correlation between the different parameters.

**[0036]** According to another embodiment, the control unit 21 comprises a neural network configured for determining the operating point of the vacuum pump 1 based on the retrieved measurements. The neural network is configured to analyse the evolution of the state of the vacuum pump 1 and the evolution of the measured parameters over time in order to determine the influence of the different controlling parameters. A learning phase comprising sequential steps of activation of the different features of the pump may be required to set up the neural network. The permanent analysis achieved by the neural network enables determining the optimal operating point according to the searched goal and the different constraints. As for the previous embodiment, these constraints refer to a preferred operating mode which is selected by the user in order to set different thresholds associated with different parameters for example the temperature threshold for an operating mode maximizing the lifetime will be lower than the temperature threshold as-

sociated with an operating mode maximizing the performance (minimal time to reach the desired pressure).

**[0037]** The control unit 21 may thus be configured to take into account current and past retrieved measurements for determining the operating point of the vacuum pump 1. Furthermore, each new measurement may be used to update a threshold value or to update the influence of a parameter on the state of the vacuum pump 1.

**[0038]** Thanks to the analysis of the evolution of the state of the vacuum pump 1 and the influence of the different parameters over time, the neural network may also be able to determine a configuration or a function of different components of the vacuum pump 1 with respect to each other.

**[0039]** According to a third embodiment, the control unit 21 comprises a combination of fuzzy logic defining rulesets and neural network configured to adapt the values associated to the qualifiers defined in the rulesets. The operating point is then defined based on current and previous measurements and the values associated with the qualifiers may be adapted over time. Furthermore, the control unit 21 may automatically adapt the determination of the operating point to the replacement of a component of the vacuum pump 1, even if the new components has different features than the replaced component.

**[0040]** The control unit 21 may be provided through the use of a dedicated hardware as well as hardware capable of executing software. When provided by a processor, the control unit 21 may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, microcontroller, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read-only memory (ROM) for storing software, random access memory (RAM), and non-volatile storage. Other hardware, conventional and/or custom, may also be included.

**[0041]** Furthermore, the vacuum pump 1 comprises communication means which may be wireless communications means to enables communications between different components of the vacuum pump 1 notably between the control unit 21 and the different sensors as well as between the control unit 21 and the controlling means enabling the application of an operating point to the vacuum pump 1 (control of the rotational speed of the rotors 5...).

**[0042]** As disclosed previously, the present invention may also be applied on a vacuum system comprising one or several vacuum pumps and possibly additional components such as valves. The different features described for the vacuum pump 1 may be applied to the vacuum system 1.

**[0043]** Figure 3 represents an example of a vacuum

system 100 comprising a roughing pump 101, a first turbomolecular pump 103 coupled to the roughing pump 101 via a first electronic valve 105, a second turbomolecular pump 107 coupled to the first turbomolecular pump 103 via a second electronic valve 109 and a vacuum chamber 115 coupled to the second turbomolecular pump 107, the three pumps 101, 103 and 107 are therefore connected in series. The vacuum system 100 also comprises a first pressure gauge 111 arranged between the roughing pump 101 and the first turbomolecular pump 103 and a second pressure gauge 113 arranged between the first turbomolecular pump 103 and the second turbomolecular pump 107. The vacuum system 100 presented in fig.3 remains simple for sake of clarity but in practice, such vacuum system 100 would comprise many other sensors such as temperature sensors arranged within the different vacuum pumps 101, 103, 107, flow rate sensors associated with the purge gas supplying device or the cooling fluid circuit of the different vacuum pumps 101, 103, 107 and possibly other types of sensors as disclosed previously.

**[0044]** The vacuum system 100 also comprises a control unit 21 capable of applying fuzzy logic and/ or neural network as disclosed previously in the case of a vacuum pump 1 and is configured to recursively determine an operating point of the vacuum system (activation and control of the different pumps as well as control of the different valves) based on the different measurements retrieved from the different sensors of the vacuum system and according to an operating mode selected by the user.

**[0045]** In the following example, the control unit 21 comprises a neural network.

**[0046]** When starting the evacuation of the vacuum chamber 115, the roughing pump 101 will be turned on which will cause a pressure drop in both first and second pressure gauges 111 and 113.

**[0047]** Next, the first turbomolecular pump 103 will be turned on which causes a pressure drop in the second pressure gauge 113 but not in the first pressure gauge 111.

**[0048]** Consequently, the neural network of the control unit 21 may determine that the first pressure gauge 111 is located between the roughing pump 101 and the first turbomolecular pump 103.

**[0049]** In the following step of the process, the second turbomolecular pump 107 is turned on which does not cause any pressure drop in the first pressure gauge 111 and in the second pressure gauge 113. The neural network may then determine that the second pressure gauge 113 is located between the first turbomolecular pump 103 and the second turbomolecular pumps 107.

**[0050]** Based on this analysis of the different parts of the vacuum system 100, a neural network of a control unit 21 associated with the vacuum system 100 may establish some rules to control the vacuum system 100. For example, the control unit 21 may decide to set the first turbomolecular pump 103 in a stand-by mode as long as the pressure in the second pressure gauge 113 or the

drive power of the second turbomolecular pump 107 does not significantly increase in order to decrease the wear and power consumption associated with the first turbomolecular pump 103.

**[0051]** However, the second turbomolecular pump 107 could not be switched to a stand-by mode as there is no pressure gauge to monitor the impact of such adaptation in a stand-by mode. Such monitoring of the behaviour of the vacuum system 100 may be achieved constantly over time so that the control unit 21 may adapt to a change during the process. For example, if an increase of the gas load to be evacuated from the vacuum chamber 115 occurs, the stand-by mode of first turbomolecular pump 103 may be disabled to ensure the safety of the vacuum system 100.

**[0052]** Furthermore, in case of a change in the vacuum system 100, for example the replacement of an element of the vacuum system 100 due to maintenance or for an upgrade to a newer element, the control unit 21 is capable of detecting such replacement and to adapt the rules and the determination of the operating point to take into account the features of the new element. The vacuum system 100 is then constantly adapting to any changes that can occur during the lifetime of the vacuum system 100.

**[0053]** Furthermore, in the different embodiments disclosed previously, the control unit 21 may be configured for assessing a remaining useful lifetime of a vacuum pump 1 or parts of the vacuum pump 1 based on the operating points applied over time and/or from the measurements achieved over time and for emitting a warning signal when the determined remaining useful lifetime is below a predetermined threshold. As the estimation of the remaining useful lifetime takes into account the different states of the vacuum pump 1 over time, such estimation may be very accurate so that the lifetime of the parts is optimized while limiting the risk of a failure.

**[0054]** Such feature of the control unit 21 may also apply in the case of a vacuum system 100 for assessing a remaining useful lifetime of the elements of the vacuum system 100 such as the vacuum pumps 101, 103, 107 or the valves 105, 109 or any other elements of the vacuum system 100.

**[0055]** Thus, by monitoring the state of a vacuum pump or a vacuum system thanks to a plurality of sensors configured for measuring the parameters influencing such state and by using these parameters measurements to determine an operating point associated with a selected mode thanks to the use of a fuzzy logic and/or neural network processing means, the present invention enables optimizing the functioning of the vacuum pump of the vacuum system according to the application and the requirements of the user. Moreover, such adaptation of the vacuum equipment to the users requirements are achieved automatically by the vacuum equipment and does not require a tailor-made configuration of the vacuum equipment during manufacturing to adapt the configuration of the said equipment to the application and the requirements of the user.

**[0056]** Furthermore, the use of neural network processing means enable adapting the control of the vacuum equipment to any changes in the configuration of the vacuum equipment. The present invention also provides an accurate estimation of the remaining useful lifetime to warn the user when an element requires maintenance or replacement before a breakdown occurs.

## Claims

### 1. Vacuum pump (1) comprising:

- a plurality of sensors (11, 13, 15, 17, 19) configured for measuring parameters associated with a state of the vacuum pump (1),
- a control unit (21) configured for retrieving measurements from the sensors (11, 13, 15, 17, 19) and for determining recursively over time an operating point of the vacuum pump (1) based on one side on the retrieved measurements and on the other side on an operating mode of the vacuum pump (1) selected by a user among a plurality of operating modes and for applying the determined operating point.

2. Vacuum pump (1) in accordance with the previous claim wherein at least some of the parameters associated with a state of the vacuum pump (1) are cross-correlated parameters.

3. Vacuum pump (1) in accordance with one of the previous claims wherein the plurality of operating modes refers to operating modes among the following list:

- a mode configured for optimizing a performance of the vacuum pump (1),
- a mode configured for maximizing a lifetime of the vacuum pump (1),
- a mode configured for limiting a functioning cost of the pump (1).

4. Vacuum pump (1) in accordance with one of the previous claims wherein the control unit (21) is configured to apply a fuzzy logic on the retrieved measurements to determine the operating point of the vacuum pump (1).

5. Vacuum pump (1) in accordance with one of the claims 1 to 3 wherein the control unit (21) comprises a neural network configured for determining the operating point of the vacuum pump (1) based on the retrieved measurements.

6. Vacuum pump (1) in accordance with one of the previous claims wherein the parameters associated with a state of the vacuum pump (1) are chosen among the following list:

- a temperature of the vacuum pump (1),
- a rotational speed of a rotor (5) of the vacuum pump (1),
- a flow rate of a cooling fluid,
- a purge gas (F2) flow,
- a pressure level at an input (1a) of the vacuum pump (1) or in a chamber coupled to the vacuum pump (1),
- a valve setting,
- vibrations of a part of the vacuum pump (1)
- intensity of a motor of the vacuum pump (1),
- a noise level of the vacuum pump (1),
- ultrasonic from the vacuum pump (1).

7. Vacuum pump (1) in accordance with one of the previous claims wherein the application of the determined operating point comprises a control of a supply current controlling the rotational speed of the rotor (5) and a control of a flow rate of a cooling fluid.

8. Vacuum pump (1) in accordance with one of the previous claims wherein the control unit (21) is configured to take into account current and past retrieved measurements for determining the operating point of the vacuum pump (1).

9. Vacuum pump (1) in accordance with one the previous claims wherein the control unit (21) is configured for assessing a remaining useful lifetime of the vacuum pump or parts of the vacuum pump (1) according the operating points applied over time and for emitting a warning signal when the determined remaining useful lifetime is below a predetermined threshold.

10. Vacuum system (100) comprising a vacuum chamber (115), at least a vacuum pump (101, 103, 107) and a plurality of sensors (111, 113) configured for measuring parameters associated with a state of the vacuum system (100) and a control unit (21) configured for retrieving measurements from the sensors (111, 113) and for determining recursively over time an operating point of the vacuum system (100) based on one side on the retrieved measurements and on the other side on an operating mode of the vacuum system (100) selected by a user among a plurality of operating modes and for applying the determined operating point.

11. Vacuum system (100) in accordance with the previous claim wherein the sensors (111, 113) refer to pressure sensors (111, 113) located in different parts of the vacuum system (100), temperature sensors located in different parts of the vacuum system (100), a sensor configured for measuring the rotational speed of a rotor of the at least one vacuum pump (101, 103, 107), a sensor configured for measuring a setting of the at least one valve.



12. Vacuum system (100) according to claim 10 or 11 wherein the control unit (21) comprises a neural network configured for determining the operating point of the vacuum system (100) based on the retrieved measurements. 5
13. Vacuum system (100) according to the previous claim wherein the neural network is configured to produce an adaptation of the operating point over time according to previous states of the vacuum system (100). 10
14. Vacuum system (100) in accordance with claim 12 or 13 wherein the neural network is configured to determine a position and a function of different components of the vacuum system (100) based on past measurements and past states of the vacuum system (100) and wherein the neural network is configured to adapt the operating point of the vacuum system (100) when a new component is introduced in the vacuum system (100). 15 20

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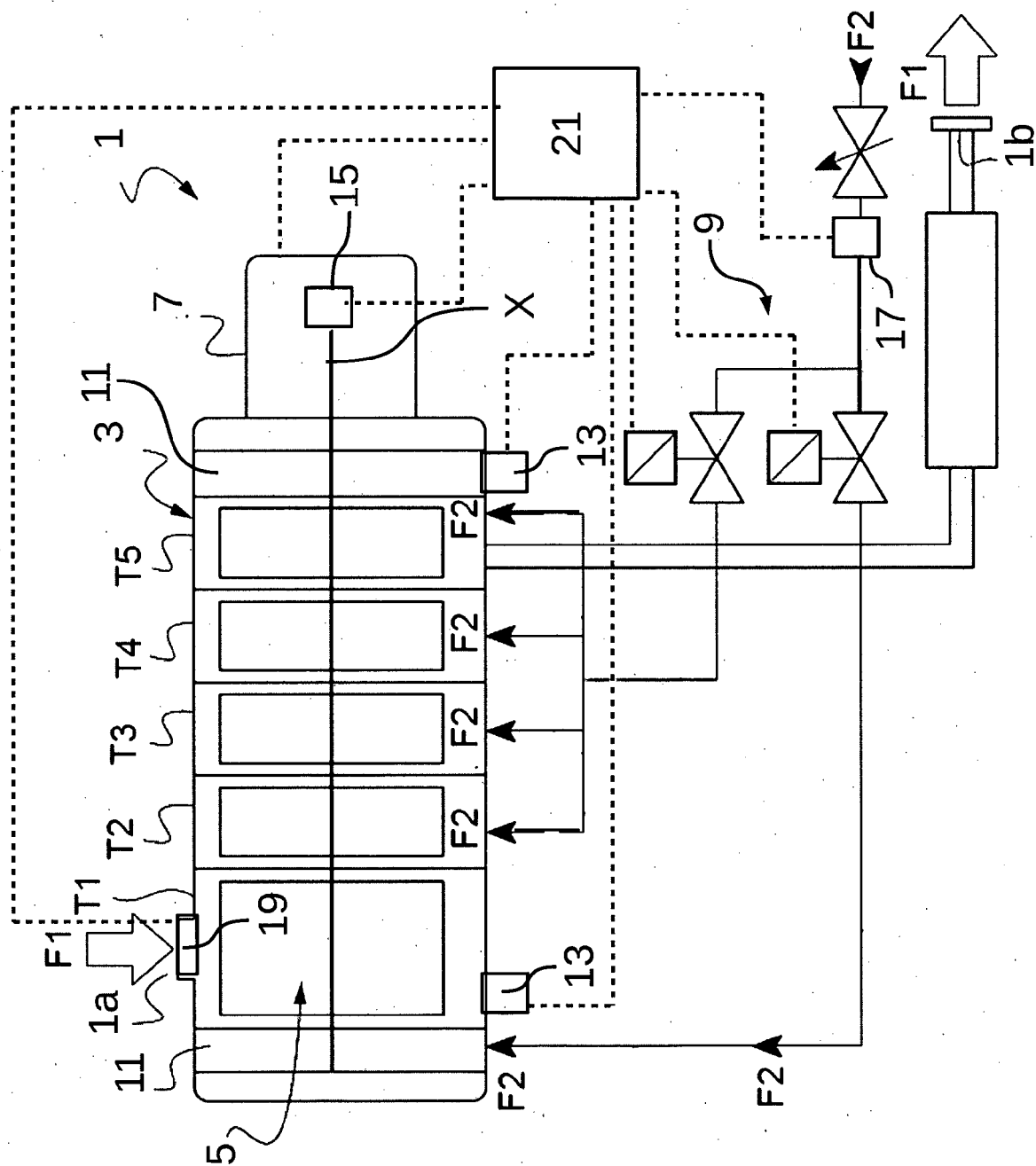


Fig.1

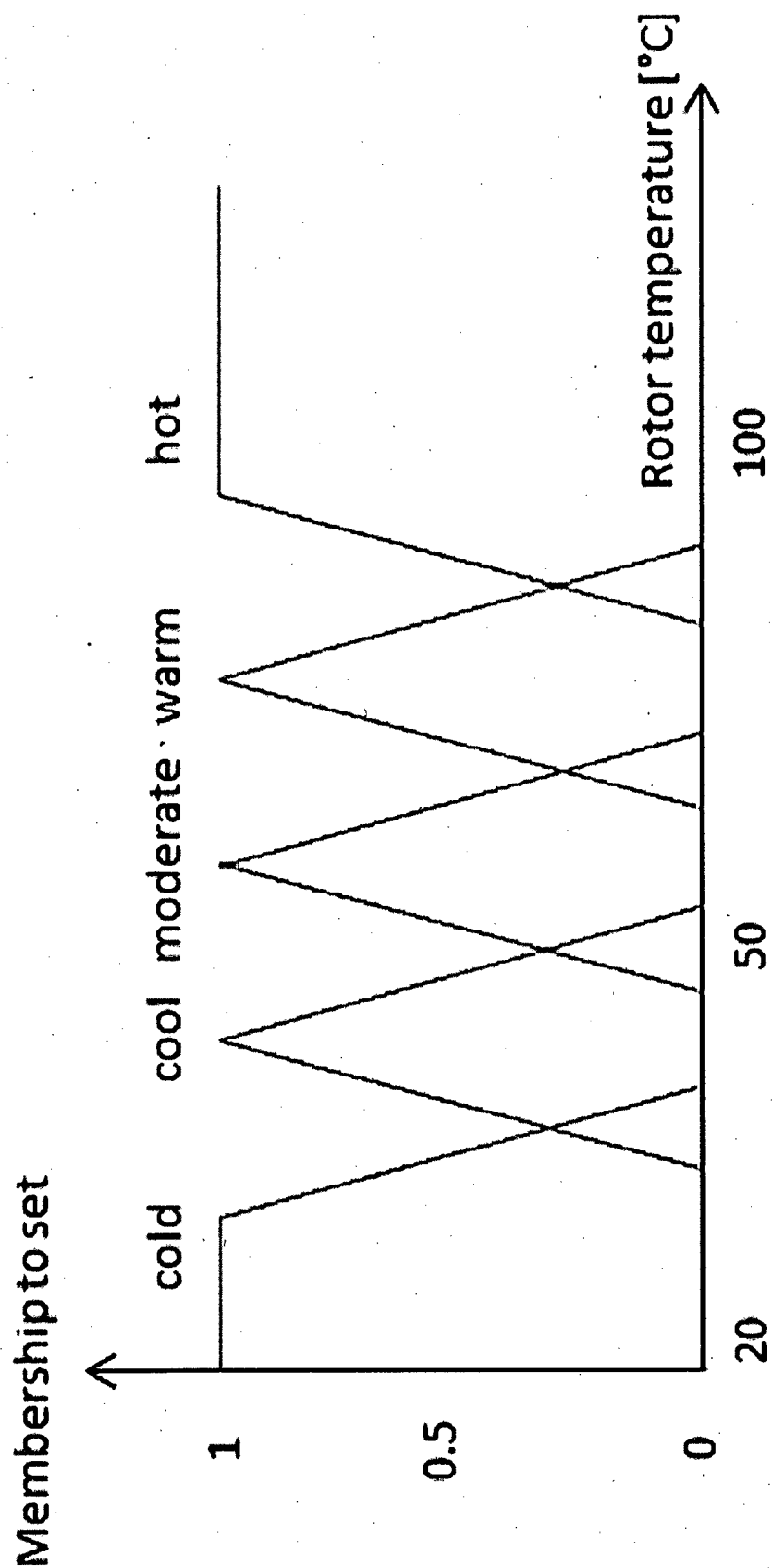


Fig.2

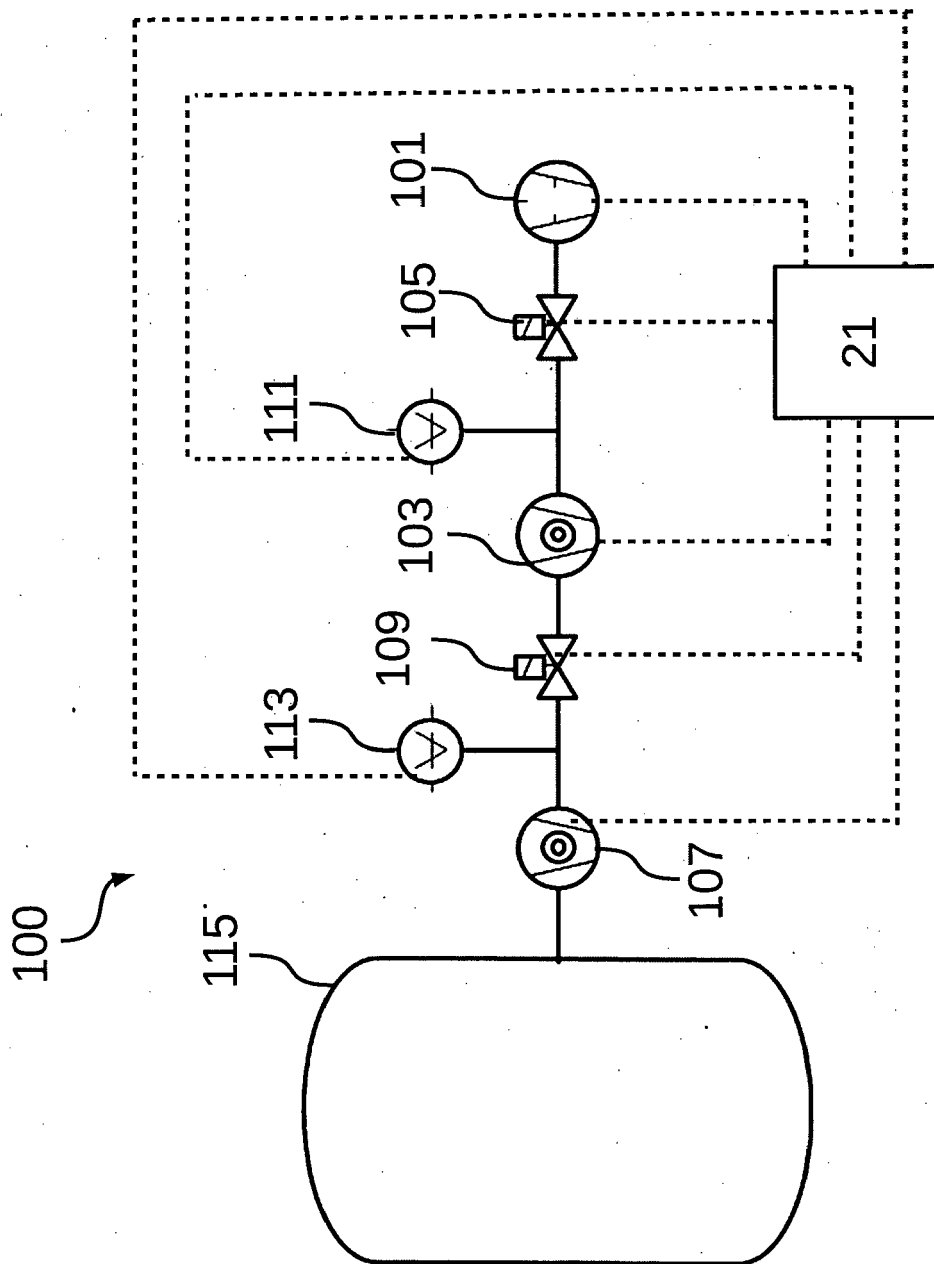


Fig.3



## EUROPEAN SEARCH REPORT

Application Number

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| DOCUMENTS CONSIDERED TO BE RELEVANT                                                                                                                                                                                                                    |                                                                                                                                        |                                                                                                                                                                                                                                                                                       |                                                          |
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| Category                                                                                                                                                                                                                                               | Citation of document with indication, where appropriate, of relevant passages                                                          | Relevant to claim                                                                                                                                                                                                                                                                     | CLASSIFICATION OF THE APPLICATION (IPC)                  |
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| X                                                                                                                                                                                                                                                      | US 5 443 368 A (WEEKS ALAN L [US] ET AL) 22 August 1995 (1995-08-22)<br>* column 3, line 35 - column 8, line 5;<br>figures 1-6 *       | 1-14                                                                                                                                                                                                                                                                                  | F04C25/02<br>F04D17/16<br>F04D19/04                      |
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| The present search report has been drawn up for all claims                                                                                                                                                                                             |                                                                                                                                        |                                                                                                                                                                                                                                                                                       |                                                          |
| Place of search<br><b>Munich</b>                                                                                                                                                                                                                       |                                                                                                                                        | Date of completion of the search<br><b>16 May 2022</b>                                                                                                                                                                                                                                | Examiner<br><b>Jurado Orenes, A</b>                      |
| CATEGORY OF CITED DOCUMENTS<br>X : particularly relevant if taken alone<br>Y : particularly relevant if combined with another document of the same category<br>A : technological background<br>O : non-written disclosure<br>P : intermediate document |                                                                                                                                        | T : theory or principle underlying the invention<br>E : earlier patent document, but published on, or after the filing date<br>D : document cited in the application<br>L : document cited for other reasons<br>.....<br>& : member of the same patent family, corresponding document |                                                          |

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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