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(71) Applicant:
Osram Gesellschaft mit beschränkter Haftung, 81543, Munich, DE

(72) Inventor:
Baier, Markus, 81541, Munich, DE; Dobler, Bastian, 82008, Unterhaching, DE; Flesch, Peter, 10625, Berlin, DE; Müller, Jürgen, 12161, Berlin, DE

(56) Documents considered for the assessment of patentability:

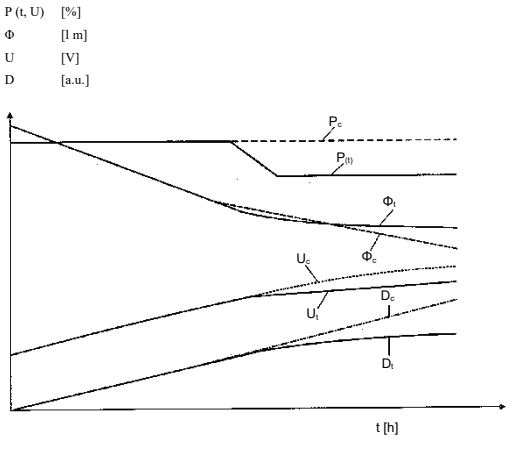
DE	**102008059483**	**A1**
US	**71 56 525**	**B2**
US	**2009/02 78 469**	**A1**
US	**2006/02 73 744**	**A1**
EP	**1 976 343**	**A1**
WO	**2007/0 46 795**	**A1**

Examination request pursuant to Section 44 of the Patent Act has been filed.

The following information has been taken from the documents submitted by the notifying party.

(54) Title: **Method for optimizing the operation of a high-pressure discharge lamp**

(57) Summary: The invention relates to a method for extending the service life of a high-pressure discharge lamp, comprising a gas discharge lamp burner made of quartz glass, which is operated with a time-variable electrical power P(t), wherein the time-variable electrical power satisfies the following relationship: $P(t) = P_{Nom}\text{-}G(t)\text{-}G(U)\text{-}G(AP)$; PNom is the nominal wattage of the high-pressure discharge lamp, G(t) is a weighting factor that depends on the cumulative burning time, G(AP) is a weighting factor that depends on certain factors such as the number of lamp starts, and G(U) is a weighting factor that depends on the lamp voltage.



Description

Technical field

[0001] The invention relates to a method for extending the service life of a high-pressure discharge lamp with a gas discharge lamp burner made of quartz glass.

Background

[0002] The invention is based on a method for extending the service life of a high-pressure discharge lamp of the type in the main claim.

[0003] A method for operating a high-pressure discharge lamp is known from US 2008/0192211, in which the lamp voltage is measured and a predetermined lamp current is set on the basis of the lamp voltage, so that the power applied to the lamp decreases as the lamp voltage increases, in order to slow down the electrode burn-back.

[0004] There is no time dependency here. A method for operating a high-pressure discharge lamp is known from DE 195 40 326, in which the cumulative operating time of the gas discharge lamp is measured and the power at the gas discharge lamp is increased with increasing cumulative operating time in order to compensate for the age-related loss of luminous flux.

[0005] Finally, DE 195 40 326 discloses a method for operating a high-pressure discharge lamp, in which the lamp voltage and the cumulative burning time are measured and, using the lamp voltage and the cumulative burning time, the power at the gas discharge lamp is increased with increasing cumulative burning time and with increasing lamp voltage up to a maximum value of the burning voltage, the power at the gas discharge lamp being reduced again after a maximum value of the burning voltage has been reached.

Objective

[0006] The objective of the invention is to provide a method of operating a high intensity discharge lamp in a manner that either extends the useful life of the high intensity discharge lamp or, alternatively, improves the performance of the high intensity discharge lamp.

Summary

[0007] According to the invention, the solution of the problem is carried out by means of a method for the optimized operation of a high-pressure discharge lamp, comprising a gas discharge lamp burner made of quartz glass, which is operated with an electrical power P(t) that varies over time, wherein the electrical power that varies over time satisfies the following relationship: $P(t) = P_{Nom}$-G(t)-G(U)-G(AP), where P_{Nom} is the nominal wattage of the high-pressure discharge lamp, G(t) is a weighting factor that depends on the cumulative burning time, G(AP) is a weighting factor that depends on certain factors such as the number of lamp starts, and G(U) is a weighting factor that depends on the lamp voltage. This ensures that the power management system is optimized for the high-pressure discharge lamp, which can either extend the useful life of the high-pressure discharge lamp or, alternatively, improve the performance of the high-pressure discharge lamp.

[0008] In this case, the weighting factor G(AP) preferably depends on the light reduction caused by the devitrification of the gas discharge lamp burner of the high pressure discharge lamp. Preferably, the weighting factor G(AP) can also depend on the number of lamp starts.

[0009] Furthermore, the weighting factor G(AP) can also depend on the operating time of the high-pressure discharge lamp outside its nominal power range.

[0010] Further advantageous developments and embodiments of the method according to the invention for extending the service life of a high-pressure discharge lamp result from further dependent claims and from the following description.

Brief description of the drawing(s)

[0011] Further advantages, features, and details of the invention will become apparent from the following description of exemplary embodiments and from the drawings, in which identical or functionally identical elements are provided with identical reference signs. Shown are:

[0012] Fig. 1is a graph of the power applied to the lamp, the burning voltage, the light flux, and the devitrification as a function of the cumulative lamp burning time,

[0013] Fig. 2is a graph of the weighting factor G(t) as a function of the cumulative lamp burning time,

[0014] Fig. 3is a graph of the weighting factor G (U) as a function of the lamp voltage U,

[0015] Fig. 4 is a graph of the weighting factor G (AP) as a function of the normalized light output of the gas discharge lamp burner,

[0016] Fig. 5 shows an advantageous arrangement for measuring the light output of the gas discharge lamp burner.

Preferred embodiment of the invention

[0017] According to the invention, a constant power is no longer applied to the high-pressure discharge lamp over the cumulative operating time, but the power is calculated from various weighting factors. Since the devitrification of the quartz bulb, the electrode burn-back and the chemical processes in the arc tube change during the service life and are significantly influenced by the operating temperature, it is important and helpful to control the operating temperature not only by cooling but also, and especially, by means of the power input.

[0018] In a first embodiment, the operating method provides for a setpoint power that is adapted to the age of the HID burner, i.e., the operating hours that have already elapsed. The operating hours that have already elapsed are also referred to below as the cumulative lamp burning time. The elapsed time can be determined very easily and, with the help of non-volatile storage devices such as EEPROM, FLASH, or FRAM, can also be logged when the operating device for the high-pressure discharge lamp is switched off.

[0019] The power applied to the high-pressure discharge lamp according to the method of the invention is calculated as follows:
$P(t) = P_{Nom} \cdot G(t) \cdot G(U) \cdot G(AP)$. Here, G(t) describes the time dependence on the operating time t that has already elapsed, G(U) describes a modeling using the lamp voltage U, and G(AP) summarizes the influence of other parameters, such as the number of ignitions carried out or the devitrification of the gas discharge lamp burner, etc. The factors can be used together, but also independently of each other.

[0020] Fig. 1shows the progress of various parameters as a function of the cumulative lamp burning time. The parameter curves are each plotted twice: once for a state-of-the-art method with a constant power applied to the lamp over the service life, and once for the method according to the invention with a variable power applied to the lamp over the service life. The solid lines represent the curves with optimized power control according to the method according to the invention, and the dashed lines those without optimized power control according to the state of the art.

[0021] The constant power Pc applied over the cumulative burning time of the high-pressure discharge lamp is, by its very nature, a horizontal straight line. In the method according to the invention, the power applied to the high-pressure discharge lamp is reduced from a predetermined cumulative burning time in order to contain the progressive devitrification of the gas discharge lamp burner. At time t1, for example, the change from the area with nominal power to operation at reduced setpoint power takes place. Later, at time t2, the target value of the reduced power is reached; for later times, the lamp power remains at this value. The transition to lower power with increasing lifetime compared to standard operation according to the state of the art initially reduces the luminous flux Φt; however, it is higher a certain time later, when the luminous flux Φc would already drop significantly due to progressive devitrification when operated at constant power, and offers a longer time span, thus extending the lamp lifetime. The long-term effect of slowed devitrification due to reduced power input is particularly noticeable here. High-pressure discharge lamps with a quartz glass burner show a progressive devitrification of the burner with increasing cumulative burning time. This is reflected in an increasing roughening of the inner wall of the burner, which shows reduced light transmission and thus reduces the luminous flux Φ of the lamp. According to the invention, devitrification of the inner wall of the gas discharge lamp burner is significantly slowed down by a power reduction dependent on various parameters starting at a certain cumulative lamp burning time, in order to increase the luminous flux at an advanced cumulative burning time compared to normal operation despite a lower power applied to the high-pressure discharge lamp. Another advantage of the reduction of devitrification is the prevention of the probability of bursting of the gas discharge lamp burner and the associated safety aspect. An end-of-life voltage threshold, which, if exceeded, will cause the operation to be aborted for safety reasons due to a possible bursting of the gas discharge lamp burner, can advantageously be shifted to higher values.

[0022] The reduction or increase in power can be done linearly with time, as shown in the figure. However, it can also be carried out in stages or exponentially. The proposed linear change results in a virtually invisible change for the user. As shown in the example in the diagram, power changes in the range of 1% to 15% are sufficient.

[0023] Φ_c is the luminous flux when the high-pressure discharge lamp is operated at constant power, Φ_t is the luminous flux when the lamp is operated using the method according to the invention. Φ_c is only for a short time after the power to the lamp is reduced higher than Φ_t due to the increased devitrification of the gas discharge lamp burner, the light output drops significantly more with cumulative operating time than when the high pressure discharge lamp is operated with the method according to the invention.

[0024] When operating the high-pressure discharge lamp using the method according to the invention, the lamp voltage U_t also increases with increasing cumulative operating time, but to a lesser extent than the lamp voltage U_c in conventional operation at constant power.

[0025] The effect can be clearly seen in the devitrification curve D. In conventional operation with constant power, the devitrification D_c increases continuously with the cumulative burning duration, whereas in operation of the high-pressure discharge lamp according to the invention, the devitrification D_t increases only to a very slight extent from the time of the power reduction. This is due to the reduced load on the burner inner wall at lower power.

[0026] Fig. 2 shows an example of a graph of the weighting factor G(t) as a function of the cumulative lamp burning time. The solid line describes the curve G(t) for a first embodiment of the method. The G(t) factor is one up to the time t1 of the accumulated burning time; from this point in time until the time t2, which can be around 1000 h for a standard projection lamp, it is continuously reduced, and then remains at a value of 0.97 from this point in time. This value can vary from application to application and from lamp to lamp.

[0027] In a second embodiment of the method according to the invention, the power is increased slightly at the beginning of the cumulative burning time, as shown by the dotted line in Fig. 2. Within the first 150 hours, i.e., up to time t0a, the burner can be operated, for example, at an increased power compared to its nominal power in order to favor the diffusion of hydrogen from the burner. The hydrogen present has a significant influence on the tungsten halogen cycle and thus on the blackening of the inner glass bulb wall due to precipitated tungsten. Any blackening that occurs has a negative effect on the luminous flux. Increasing the power at the beginning of the burner's service life can have a positive effect on the blackening behavior by accelerating the diffusion of hydrogen. In addition, the luminous flux is intrinsically higher due to the higher power at the beginning of the cumulative burning time.

[0028] After a linear power reduction at time t0b, the burner then operates as standard at its nominal power. After a period of time that is characteristic of the burner type (and determined experimentally), the power supplied to the burner is reduced from time t1. This reduces the thermal load on the glass bulb and thus also slows down the progress of devitrification. Electrode burn-back is also inhibited. Both have a positive effect on the reduction of the luminous flux. On the one hand, the progression of devitrification with the milky clouding of the glass bulb is reduced, and on the other hand, the widening of the radiation location is reduced by the slowed electrode wear. From t2 onwards, the power applied to the high-pressure discharge lamp remains constant at 97% of the nominal power.

[0029] In another embodiment of the method according to the invention, which is designed for maximum performance of the high-pressure discharge lamp and not for maximum service life, the power remains at the nominal power (dashed line) between the time t1 and the time t1', in order to then be increased to approx. 105% of the nominal power to compensate for the loss of luminous flux due to bulb blackening and electrode burn-back. However, the end of the lamp's service life is then very quickly reached since the power cannot be increased further, but the luminous flux will quickly decrease due to the effects mentioned above.

[0030] Fig. 3 shows a graph of the weighting factor G(U) as a function of the lamp voltage. As described above, G(U) is a modeling of the power P(t) over the lamp voltage U. G(U) has the value of one for low burning voltages, as they usually occur with new high-pressure discharge lamps, and a reduced value of 0.97 in this example for higher burning voltages, as they usually occur at the end of the service life of high-pressure discharge lamps. The value is continuously reduced from a certain voltage U1, starting from 1, until it reaches 0.97 for voltages greater than U2.

[0031] The decrease or increase of the power can be done linearly with the lamp voltage, as shown in the figure. However, it can also be carried out in stages or exponentially. The proposed linear change results in a virtually invisible change for the user. As shown in the example in the diagram, power changes in the range of 1% to 15% are sufficient.

[0032] Fig. 4 shows an example of the graphic representation of the weighting factor G(AP). G(AP) describes the dependence of the power reduction on other factors, e.g., the number of ignitions or the stray light. Light reduction caused by de-glazing was chosen as an exemplary design.

[0033] This requires a sensor that detects the radiation from the burner. Since a reference to the devitrification should be established, a sensor above the burner was selected here. Devitrification starts at the top of the burner, where it is hottest, and reduces the "direct" radiation towards the sensor, as portions of the radiation are scattered away. If a sensor in the near IR range is selected, the sensor can be placed outside the reflector, since the reflector coating is often "transparent" in the IR and UV. The graph shows that, starting from a scattered radiation of, for example, 3%, the weighting factor G(AP) decreases linearly from 100%. From a scattered radiation of 18%, for example, the weighting factor G(AP) then remains the same again at 97%.

[0034] Fig. 5shows an advantageous arrangement for measuring the light output of the gas discharge lamp burner in order to measure the scattered radiation for the above exemplary embodiment. The gas discharge lamp burner 5 is embedded in a reflector 3, as is common for many projection lamps; however, as mentioned above, the reflector is transparent to near-IR radiation. A light sensor 2 is now placed outside this reflector, which measures the direct radiation of the gas discharge lamp burner. On the basis of this measured value, the normalized light output of the gas discharge lamp burner Φ/Φ_{nom} can be calculated, and from this, based on the relationship in Fig. 4, the weighting factor G(AP).

[0035] Since the projectors can be operated standing on the table or hanging overhead from the ceiling and the top of the lamp is therefore not fixed per se, the light sensor (2) can, for example, be mounted to rotate around the main axis through the electrodes of the gas discharge lamp burner and thus always automatically adjust itself to the top side of the burner with the stronger devitrification. Due to the thermal conditions, the devitrification of the gas discharge lamp burner is always most pronounced at its upper side. The top side is the upper side of the gas discharge lamp burner in a gravitational sense. Automatic adjustment can be achieved, for example, by using a heavier counterweight attached opposite sensor 2, which will always rotate to the underside of the gas discharge lamp burner. The simplicity of the mechanism ensures that it can be used safely.

[0036] A further possibility would be the dual design of the light sensor 2 for normal operation, e.g., on a table, and overhead operation, e.g., on a ceiling. Many video projectors have a position sensor so that they can react to such different operating conditions and adjust the image accordingly. This position sensor can be queried and the corresponding light sensor 2 can be selected based on this information.

[0037] The above embodiment is merely an example of the calculation of the weighting factor G(AP). As mentioned above, this weighting factor can depend on various conditions such as the number of ignitions, the operating time at powers outside the nominal range, the decrease in luminous flux, etc. All these factors are included in the calculation of the weighting factor G(AP). However, a simple model as shown in Fig. 4 will often be sufficient.

[0038] Finally, and in summary, the calculation of the optimum power for a gas discharge lamp burner according to the invention:

$$P_{opt} = G(t)\cdot G(U)\cdot G(AP)\cdot P_{nominal}$$

Reference designator list

P_c	Constant power applied to the high-pressure discharge lamp over the operating time according to the state of the art.
P(t)	Variable power applied to the high-pressure discharge lamp over the burning period according to the method of the invention
Φ_c	Luminous flux at constant power P_c
Φ_t	Luminous flux at variable power P(t)
U_c	Lamp voltage at constant power P_c
^{U}t	Lamp voltage at variable power P(t)
D_c	Devitrification at constant power P_c
D_t	Devitrification at variable power P(t)
G(t)	Weighting factor based on the cumulative lamp burning time
G(U)	Weighting factor as a function of the lamp voltage
G(AP)	Weighting factor depending on various conditions

2 Radiation sensor
3 Reflector
4 Devitrification point
5 Gas discharge lamp burner

CITATIONS INCLUDED IN THE DESCRIPTION

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Cited patent literature

- US 2008/0192211 [**0003**]
- DE 19540326 [**0004**, **0005**]

Claims

1. A method for the optimized operation of a high-pressure discharge lamp, comprising a gas discharge lamp burner (5) made of quartz glass, which is operated with an electrical power P (t) that varies over time, **characterized in that** the electrical power that varies over time satisfies the following relationship: $P(t) = P_{Nom}\text{-}G(t)\text{-}G(U)\text{-}G(AP)$, where P_{Nom} is the nominal wattage of the high-intensity discharge lamp, G(t) is a weighting factor that depends on the cumulative lamp burning time, G(AP) is a weighting factor that depends on certain factors such as the number of lamp starts, and G(U) is a weighting factor that depends on the lamp voltage.

2. The method according to claim 1, characterized in that the weighting factor G(AP) depends on the light reduction caused by the devitrification of the gas discharge lamp burner (**5**) of the high pressure discharge lamp.

3. The method according to claim 1 or 2, characterized in that the weighting factor G(AP) depends on the number of lamp starts.

4. The method according to claim 1, 2, or 3, characterized in that the weighting factor G(AP) is dependent on the operating time of the high-pressure discharge lamp outside its nominal power range.

5. The method according to claim 2, characterized in that devitrification is measured by means of a light sensor (**2**) on the upper side of the gas discharge lamp burner (**5**).

6. The method according to claim 5, characterized in that the light sensor (**2**) is mechanically suspended in such a way that it rotates about an axis which is formed by the two lamp electrodes of the gas discharge lamp burner (**5**) and is always located on the upper side of the gas discharge lamp burner.

7. The method according to claim 5, characterized in that a plurality of light sensors (**2**) are present, the light sensor (**2**) located on the upper side of the gas discharge lamp burner (**5**) being selected by means of a position sensor for measuring devitrification.

Three sheets of drawings follow

Attached drawings

P (t, U)	[%]
Φ	[lm]
U	[V]
D	[a.u.]

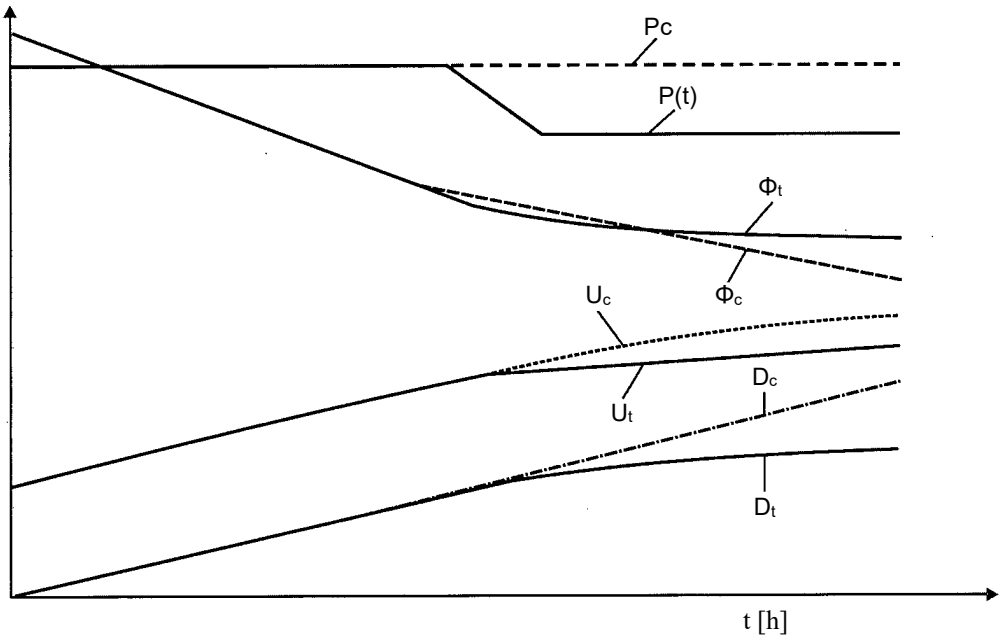

FIG. 1

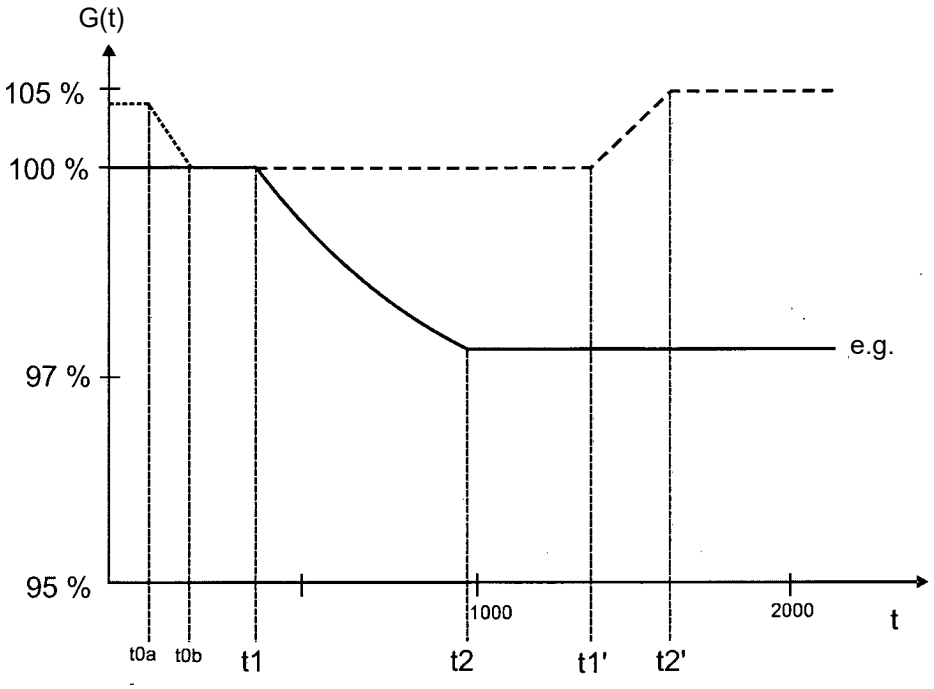

FIG. 2

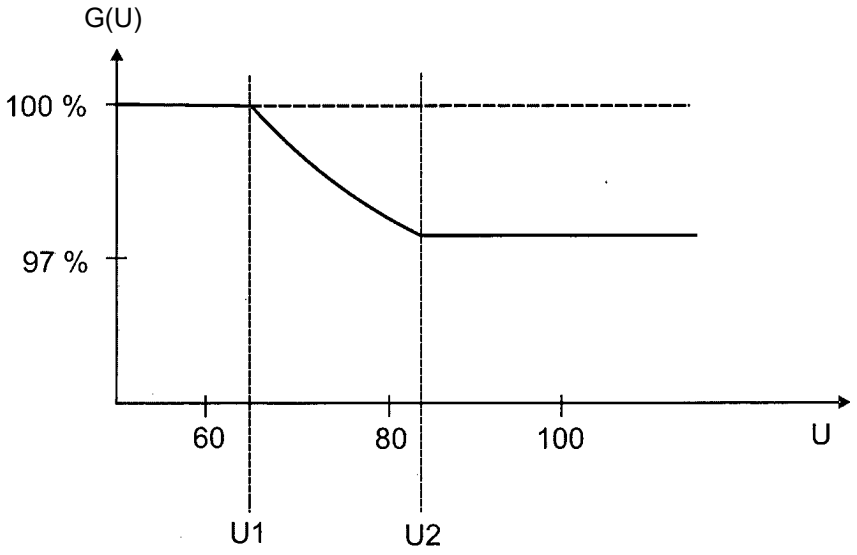

FIG. 3

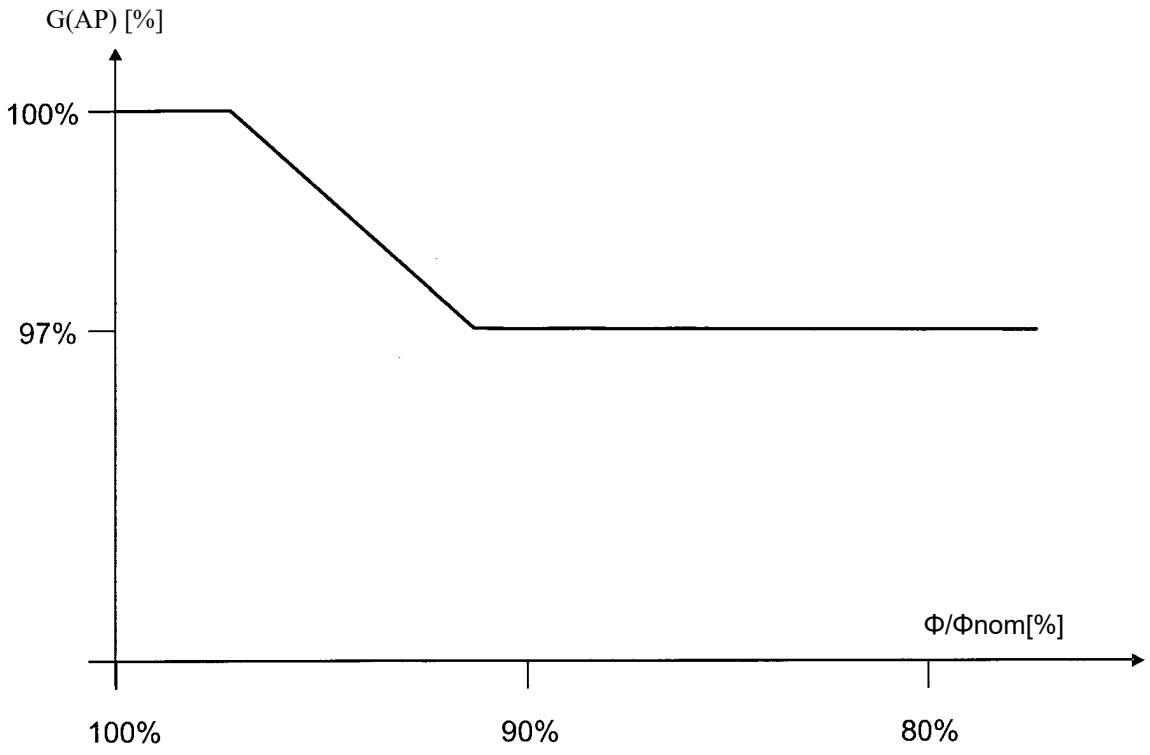

FIG. 4

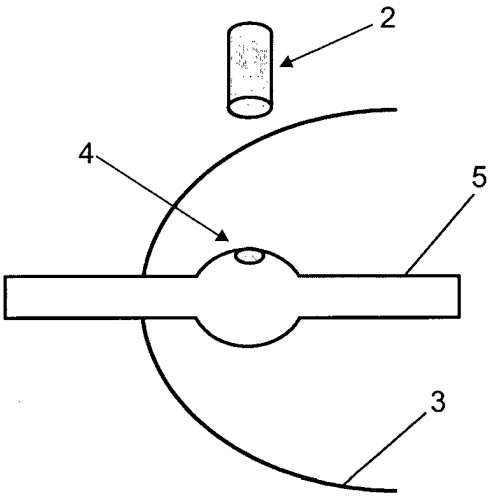

FIG. 5