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**US-A- 4 818 843**  
**US-A- 5 706 389**  
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# DESCRIPTION

**[0001]** The present invention refers to a device for generating fog and to an operating method of such device.

**[0002]** In particular, the present invention refers to a steam generating system, through electric heating of a liquid circulating in pipes or ducts.

**[0003]** Fog-generating apparatus are known, for theft prevention, entertainment, screening, defence purposes and the like, pressurized or connected downstream to at least one pump and a heat exchanger to allow taking to the vapour phase the liquid contained in the tank. The size of the thermal exchange surface of the heat exchanger depends on the value of the desired thermal power necessary to allow forming the fog.

**[0004]** The prior art of fog-generating apparatuses, for example given by patent US5706389A, deals with a device for evaporating the liquids for generating fog comprising an electrically heated heat exchanger. Such device makes it possible to quickly heat the liquids to be evaporated in a predetermined range of temperatures through the wall of the heat exchanger. The heat exchanger made of an electrically conductive material is connected to a source of electric energy for a direct heating.

**[0005]** A problem to be taken into account in fog-generating apparatuses deals with the heating time of the exchanger. Preferably, the heat exchanger must go to its thermal steady state in about one, two seconds. To do this, the heat exchanger must be optimized according to three parameters: total thermal mass; electric resistance; structural resistance. Patent US5706389A deals with and solves the problem of the heating time of the heat exchanger through a device for evaporating liquids comprising at least one section composed of an alloy of about 55% of copper and about 45% of nickel, the remaining part of such heat exchanger being of stainless steel. Preferably, such heat exchanger is a round tube with an internal diameter from 0.3 to 1 mm, with the wall of such tube having a thickness from 0.1 to 0.3 mm and a length from 120 to 1000 mm.

**[0006]** However, with these materials it is not possible to quickly reach the final temperature. For this reason, the device disclosed in patent US5706389A is unsuitable for anti-theft applications.

**[0007]** Another problem to be taken into account in fog-generating apparatuses deals with the need of measuring the temperature of the heat exchanger. Generally, the temperature quickly changes, both spot by spot and in time. For this reason, it is not possible to measure the temperature with a normal thermocouple, the thermometer mass being high with respect to the local mass of the exchanger, with the result of altering the measure with respect to reality. Moreover, such type of measure would have the limit, in any case, of being performed in a spot and with a delay given by the time constant caused by the thermometer mass. Also this

aspect becomes important, above all when there are very short time constants of the heater. Such discrepancy in response times could bring about an overheating and the consequent heater melting. However, it is necessary to be able to determine the current temperature of the heat exchanger section by section. This preferably implies the measure of the electric resistance. The heating current is also preferably controlled section by section, depending on the measured electric resistance. Patent US5706389A deals with and solves the problem of measuring the temperature of the heat exchanger through a portion of the heat exchanger designed to operate as a heating resistance having a low temperature coefficient. Such portion is directly used as measuring resistor of the temperature of the heat exchanger connected in parallel to an electronic unit, preferably arranged between the heat exchanger and the supply source. The electronic unit output is directly connected to the supply source. This implies having to use as measuring resistance a particularly costly material, which can be found with difficulty in tubes, such as constantan.

**[0008]** US-A-5 706 389, US-A-5 937 141, US-A-5 870 524 and WO-A1-94/07223 disclose prior art devices for generating fog.

**[0009]** Object of the present invention is solving the above prior art problems, by providing a device for generating fog capable to operate through the measure of an electric potential difference to thermally check the pressurized fluid before of vaporizing the pressurized fluid.

**[0010]** A further object of the present invention is providing a device for generating fog capable of continuously operate, above all in case of an electric current interruption.

**[0011]** A further object of the present invention is providing a device for generating fog in which it is possible to increase the latency time without electric supply.

**[0012]** A further object of the present invention is providing a device capable of substantially cancelling the self-consumption during the stand-by pauses, in order to save energy.

**[0013]** Another object of the present invention is providing an operating method of a device for generating fog through which it is possible to control the heating time of the heat exchanger in order to reach the standby temperature in one, two seconds, in addition to control the temperature value of a device subjected to sudden temperature gaps.

**[0014]** A further object of the present invention is providing an operating method of a device for generating fog through which it is possible to control and optimize the temperature distribution.

**[0015]** The above and other objects and advantages of the invention, as will appear from the following description, are reached with a device for generating fog, as claimed in claim 1, and with an operating method of a device for generating fog as claimed in claim 8.

**[0016]** Preferred embodiments and non-trivial variations of the present invention are the

subject matter of the dependent claims.

**[0017]** It is intended that all enclosed claims are an integral part of the present description.

**[0018]** It will be immediately obvious that numerous variations and modifications (for example related to shape, sizes, arrangements and parts with equivalent functionality) can be made to what is described, without departing from the scope of the invention as appears from the enclosed claims.

**[0019]** The present invention will be better described by some preferred embodiments thereof, provided as a non-limiting example, with reference to the enclosed drawings, in which:

- Figure 1 shows an operating diagram of an embodiment of the device for generating fog according to the present invention;
- Figure 2 shows an axonometric view of some components of an embodiment of the device for generating fog according to the present invention;
- Figure 3 shows a first connection diagram of the embodiment of the device of Figure 1;
- Figure 4 shows a second connection diagram of the embodiment of the device of Figure 1; and
- Figures 5, 6 show an axonometric view of an assembly of an embodiment of the device for generating fog according to the present invention.

**[0020]** With reference to Figure 1, it is possible to note that a device for generating fog 1 according to the present invention comprises at least one heat exchanger 10 electrically heated to be able to vaporize at least one pressurized fluid, pressurizing means 20 to be able to send the fluid from at least one tank 30 towards the heat exchanger 10, at least one electronic unit 40 to control the temperature of the heat exchanger 10 and the operation of the pressurizing means 20.

**[0021]** Advantageously, the heat exchanger 10 comprises tubular elements in contact with the pressurized fluid, each tubular element being subjected to an electric potential difference to thermally check the pressurized fluid, before and during the vaporizing step of the pressurized fluid.

**[0022]** In particular, the tubular elements of the heat exchanger 10 comprise at least one thin wall composed of at least one first layer of structurally resisting material and of at least one second layer of material having a high electric conductivity to obtain an optimum value of equivalent electric resistance, without having to increase the thermal mass of the heat exchanger 10.

**[0023]** According to a preferred variation, the tubular elements of the heat exchanger 10 comprise at least one thin wall made of titanium, the titanium being at the same time a

structurally resisting material and an optimum electric conductor to obtain an optimum value of equivalent electric resistance, without having to increase the thermal mass of the heat exchanger 10.

**[0024]** Preferably, the heat exchanger 10 is composed of a pair of sections 11 and 12 of tubular elements, each section of such pair of sections 11 and 12 being supplied with a proper electric voltage and connected to a control unit 41 and 42 to allow controlling the operation of the pressurizing means 20, in order to keep constant the lower of the temperatures detected between those of the control units 41 and 42 in order to exploit the maximum absorbed power.

**[0025]** In apparatuses with limited performances, the heat exchanger 10 can be made of a single section of tubular elements.

**[0026]** With reference to Figure 2, each of such sections of tube 11 and 12 comprises at least one portion 111, 121 adapted to operate as a resistor to allow computing the weighed mean of the steady state temperature of the respective section of tube 11 and 12, through the control units 41 and 42. Moreover, each of such sections of tube 11 and 12 comprises at least one portion 112, 122 composed of a tubular serpentine adapted to operate as fluid super-heater.

**[0027]** With reference to Figure 3, the sections of tube 11 and 12 are connected in parallel through the portions 111, 121 operating as resistor, and in series through the portions 112, 122 operating as fluid super-heater, to allow vaporizing high fluid flow rates.

**[0028]** With reference to Figure 4, the sections of tube 11 and 12 are connected in series through the portions 111, 121 operating as resistor, and in series through the portions 112, 122 operating as fluid super-heater.

**[0029]** According to a preferred configuration, each of such sections of tube 11, 12 is electrically connected to at least one accumulator 60 of the electrochemical type and a low electric voltage to allow almost instantaneously heating the heat exchanger 10 and basically cancel the internal losses of heating energy.

**[0030]** The first 41 or second 42 control unit shows an estimation of the current delivered by the accumulator 60. Such estimation is computed through the value of the voltage drop measured in at least one of such portions 111, 121 to allow knowing the status of the accumulator 60, in terms of electric charge, performance drop due to ageing, possible need for a replacement.

**[0031]** In particular, such at least one portion 111, 121 is kept cooled. According to a preferred configuration, such at least one portion 111, 121 is cooled by the fluid circulating in the device 1.

**[0032]** In particular, such electronic unit 40 is programmed to allow substantially cancelling the self-consumption during the operating pauses, in order to save energy.

**[0033]** The present invention further deals with an operating method to allow optimizing the heating times and maximizing the thermal power transferred to a fluid of a device for generating fog 1 as previously described, such method comprising the following steps:

- dry heating the heat exchanger 10;
- controlled starting the pressurizing means 20 to send fluid along the sections of tube 11, 12, till the temperature measured in at least one of such sections of tube 11, 12 starts decreasing;
- checking the operation of the pressurizing means 20, in order to keep constant the temperature of the section of tube 11, 12 which cools first in order to have the maximum available power.

**[0034]** The device for generating fog of the present invention allows obtaining the stated objects.

**[0035]** In particular, in case of anti-theft apparatuses, for which a continuous operation is required, above all in case of electric current interruption, the heat exchanger is dimensioned with a big thermal mass and thermally insulated from the external environment. The ratio between the thermal capacity and the thermal resistance, in this type of apparatuses, generates a certain time constant, for which, starting from the instant in which the electric supply drops, the expected performances can quickly decay till they stop. In particular, under stand-by conditions, in which the apparatus passes its vast majority of its lifetime, an energy self-consumption appears, caused by unavoidable losses of thermal insulation. Such self-consumption can be a strong economic loss and this practice can result in a yearly cost equal to 25% of the purchase value of an apparatus having a high class and equal to half the purchase value of a machine with a lower insulation class, namely a machine which absorbs much more energy.

**[0036]** Another solved object of the present invention is the functionality time without electric supply. The functionality time is necessarily limited and the risk of theft with "preventive disconnection" is not wholly cancelled if it is not possible to timely intervene in case of lack of current. The device of the present invention allows storing Energy, instead of in a thermal mass to be kept hot and thermally insulated, by accumulating energy in an accumulator of the electrochemical type, preferably with acid lead, and by quickly extracting it upon use. Such quick extraction, deemed critical and at the same time indispensable for an anti-theft application, makes it necessary to minimize the thermal mass of the exchanger, by taking in temperature the exchanger itself before inserting therein the fog-generating fluid. It goes without saying that the time constant of the system at start-up is directly proportional to the thermal mass/inserted power ratio.

**[0037]** In its simplest form, the apparatus consists in a tubular serpentine made of conducting material, adapted to operate as a resistor. In such resisting tubular serpentine, in which current

from the battery is made pass through a suitable control unit, the relevant currents are on the order of hundreds to thousands of Amperes. In the same tubular serpentine, once having reached the temperature which is monitored in order to close a suitable control ring through the control unit, the fog generating fluid is injected through a pump from an atmospheric tank, namely through a valve with fixed or variable opening from a pressurized tank. Passing in the tubular serpentine, the fluid is vaporized, taken to the saturated steam phase and delivered to the environment through a suitable nozzle. The high emission speed makes steam divided into small condensing centres which, by getting cooled due to the contact with the colder air, condensate into very small drops which will scatter light, causing the so-called white-out phenomenon, with absolute fog, protecting the environment.

**[0038]** The heating time of the heat exchanger is a critical element to be able to make an efficient anti-theft device. The ideal situation would be that the heat exchanger is made in order to reach its standby temperature of regime in one, two seconds. This objective can be reached by optimizing the following parameters: total thermal mass of the heat exchanger - so that, upon increasing the thermal mass, necessary time and energy must increase - and electric resistance of the serpentine in order to be perfectly suited to the battery impedance; structural resistance of the apparatus subjected to a fluid pressure. The first obvious choice could be stainless steel, a mechanically resistant metal, which can technologically be made in resisting tubes but with a small thickness, in order to minimize the thermal capacity, but unfortunately equipped with a too high resistivity for the application. In fact a serpentine made of stainless steel, if made by minimizing the metal with a very thin tube, would have an excessive electric resistance to be able to deliver enough power with 12-Volt battery voltages. If instead made by optimizing the electric resistance to be able to work at 12 Volts, it would have too big a mass and would need tens and tens of seconds to reach its temperature, in spite of the increased power. From a technologic and commercial point of view, it would be very important to succeed in making an apparatus which works with voltages on the order of 12 Volts, in order to exploit common batteries which are sold in the automotive and electric traction markets, which are thereby cheap and reliable.

**[0039]** For this purpose, three solutions are known according to the foreseen intervention of changing the electric resistance, the electric voltage or the chemical-physical characteristics of the material.

**[0040]** Change of electric resistance: this solution consists in making the tubular serpentine of stainless steel with the technologically minimum thickness possible to obtain a suitable mechanic resistance; whichever other metal equipped with enough resistivity and mechanical resistance can be used as well for such purpose, and afterwards coating through galvanic processes or vacuum coating such tubular serpentine with a thin layer of an optimum conducting metal, for example: copper, gold, etc. In this way, it is possible to regulate the equivalent electric resistance of the serpentine till the optimum value is obtained without having to increase the exchanger mass.

**[0041]** Change of the electric voltage: this solution consists in increasing the supply voltage till

the necessary power is reached in a tubular serpentine made of stainless steel, copper or whichever other material. In this case an optimum compromise can be found for any material equipped with enough mechanical resistance, with the risk however of having to manage dangerous voltages, which are costly to reach with the batteries, in case of a high resistivity metal. The same is valid for the opposite case, namely a metal with low resistivity, in cui a current of several thousands of Amperes has to be managed.

**[0042]** Choice of chemical-physical characteristics of the material. The applicant of the present invention has located the metal which optimized the voltage operation of a conventional 12 or 24 V battery. For this reason, the tubular serpentine is preferably made of titanium, a shape of a tube with thin wall capable of reaching 12 Volt with a warm up time shorter than three seconds. Alternatively, an optimum material for the serpentine could be made through layering ordinary metals with complementary electric and physical characteristics, such as for example stainless steel, copper, gold.

**[0043]** Another problem solved with the present invention deals with checking the value of the temperature of the heat exchanger. A normal thermocouple does not allow measuring the temperature of a tubular serpentine which therefore quickly changes. In fact, due to the indetermination principle between two related quantities, the thermometer mass being high with respect to the local mass of the tubular serpentine would affect the measure too much. Moreover, the measure would be performed in any case in a spot and with a delay given by the time constant caused by the thermometer mass. For this reason, the choice has been measuring the resistance of the tubular serpentine itself with a volt-ampere method, comparing it with the voltage drop on a small load in series composed of a sample element, in this case a tubular portion of the heat exchanger adapted to operate as a resistor. Knowing with enough accuracy the resistance of the sample element, it is also possible to estimate the current delivered by the battery, in this case the electro-chemical accumulator, inferring deductions on its charge and health status, till one is able to signal the performance drop due to ageing and the need for a replacement. Such test can be performer without the need of delivering fog, being it enough to simply take the device to its temperature.

**[0044]** Given the currents used, however, it is not enough to make a direct comparison assuming that the temperature of the sample element is not affected either by the circulating current or by conduction hearing: in fact, the sample element is heated a lot by changing its internal resistance. In order to reduce this phenomenon, the fog generating fluid has been directly exploited together with its circulation. In particular, the loads of the sample element have been made of a tubular shape and the fluid has been made circulate before in them and then in the tubular serpentine. In this way, their temperature is stabilized, thereby allowing an enough accurate measure for its purposes.

**[0045]** The use of this technique further allows making a weighed mean measure of the temperature, not being affected by possible too hot or too cold spots. Obviously, it is possible in principles not to check the temperature of the tubular serpentine, but the risk is overheating the fluid, making it degenerate, and one is almost compelled not to thermally insulate the tubular

serpentine to make the thermal system less unstable.

**[0046]** Another problem solved by the present invention deals with controlling and optimizing the temperature distribution. Inside the tubular serpentine several phenomena occur, due to the phase variation of the fluid, or depending on cavitation due to excess of inserted power, local boiling only on the surface, which creates a layer of insulating gas between the wall of the tubular serpentine and the liquid. Such phenomena can change the process of removing heat. The local temperature lowering under a higher absorption condition creates a local temperature lowering also of the tubular serpentine in that spot. This effect reduces the resistivity in the cooled section, the metals have a positive temperature coefficient of the resistivity, consequently linearly reducing the dissipated power in that section. This effect causes a positive reaction of the local system, which further cools the already cooled section. In other words, a device which tries in a single stage to obtain the complete vaporization can be locally unstable. To obtain the stabilization in this case, the thermal mass/device power ratio can be reduced.

**[0047]** To avoid having to recur to this reduction, the exchanger can be divided into several tubular serpentes, each with one, preferably two, independent control ring.

**[0048]** Finally, the operating method of the device of the present invention allows optimizing the heating times and maximizing the thermal power transferred to a fluid for generating fog. Through a control algorithm, it is possible to optimize the warm-up times and maximize the power transferred to the fluid. Upon turning on, each section of tube goes to its final temperature. At that time, fluid is inserted in a controlled way, starting from zero, till the first section of tube cannot keep any more the steady state temperature value. This point is the maximum flow that the device can support and manage. Now, the pump speed is regulated in order to keep constant the temperature of the section of tube which cools first. In the other sections of tube, their temperature is self-regulated in order to keep it constant.

**[0049]** Various connection schemes can be made for the tubular sections in which fluid passes, suitably combined according to the fluid being treated, depending on flow-rate and type of fog generating fluid to be vaporized.

**[0050]** With reference to Figure 3, a scheme suited to a device for generating fog with high flow-rate allows reducing the load losses through a preheating along sections of tube in parallel, when fluid is in its liquid phase, namely with more resistance to sliding and better thermal inertia, and through an overheating along sections of tube in series, when the fluid tends to its overheated vapour phase. Thereby, fluid slows down in the first ducts, by  $1/n$ , where  $n$  is the number of ducts and accelerates next to the super-heater in series for the final evaporation, where the maximum flow speed is needed, to guarantee a more violent shot.

**[0051]** With reference to Figures 5, 6, a preferred configuration of the device for generating fog 1 of the present invention comprises:

- a room 2 containing the tank 30. The tank 30 is a pressurized bag connected to pressurizing means comprising a valve, not shown. Alternatively, the tank 30 can be of the type connected to pressurizing means 20 comprising a pump;
- a nozzle 3;
- signalling LEDs 4;
- battery cables output 5;
- a 230-Volt connector 6;
- venting holes 7;
- USB;
- cables input 8;
- fan output 9.

## REFERENCES CITED IN THE DESCRIPTION

### Cited references

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### Patent documents cited in the description

- US5706389A [0004] [0005] [0006] [0007] [0008]
- US5937141A [0008]
- US5870524A [0008]
- WO9407223A1 [0008]

ANORDNING TIL AT GENERERE TÅGE OG DRIFTSMETODE AF SÅDAN ANORDNING  
PATENTKRAV

1. Anordning til at generere tåge (1), omfattende mindst en varmeveksler (10) elektrisk opvarmet for at kunne fordampe mindst  
5 en væske under tryk, tryksættende midler (20) som kan bringe væsken fra mindst en tank (30) imod nævnte varmeveksler (10), mindst en elektronisk enhed (40) til kontrol af temperaturen af nævnte varmeveksler (10) og driften af nævnte tryksættende midler (20), nævnte varmeveksler (10) omfatter rørformede dele i kontakt  
10 med nævnte væske under tryk, hver af nævnte rørformede dele bliver udsat for en potentiel elektrisk difference for at termisk kontrollere nævnte væske under tryk til kontrol af driften af nævnte tryksættende midler, før og under et fordampende trin af nævnte væske under tryk,
- 15 kendetegnet ved at nævnte varmeveksler (10) er sammensat af et par sektioner (11, 12) af rørformede dele, hver sektion af nævnte par af sektioner (11, 12) er forsynet med en elektrisk spænding og forbundet med en kontrolenhed (41, 42) for at muliggøre påvisning af temperaturen i de respektive sektioner og  
20 kontrollere driften af nævnte tryksættende midler (20), for at holde den lavere af temperaturerne konstant påvist mellem kontrolenhederne (41, 42) for at udnytte den absorberede effekt, hver af nævnte sektioner af rørformede dele (11, 12) omfatter mindst en del (111, 121) udformet til at fungere som en modstand  
25 for at muliggøre en beregning af et vægtet gennemsnit af den stabile tilstandstemperatur i de respektive sektioner af rørformede dele (11, 12) gennem kontrolenheden (41, 42), hver af nævnte sektioner af rørformede dele (11, 12) omfatter mindst en del (112, 122) bestående af en rørformet spole udformet til at  
30 fungere som væske overheder.
2. Anordning til at generere tåge (1) i henhold til foregående patentkrav, kendetegnet ved at nævnte rørformede dele af nævnte varmeveksler (10) omfatter mindst en tynd væg bestående af mindst et første lag af strukturelt resistent materiale og af  
35 mindst et andet lag af materiale med en høj elektrisk ledningsevne for at opnå en optimal værdi af tilsvarende elektrisk modstand, uden at skulle forøge den termiske masse af nævnte varmeveksler (10).
3. Anordning til at generere tåge (1) i henhold til  
40 patentkrav 1, kendetegnet ved at nævnte rørformede dele af nævnte

varmeveksler (10) omfatter mindst en tynd væg fremstillet af titanium, titanium er et strukturelt resistent materiale og samtidigt en optimal elektrisk leder for at opnå en optimal værdi af tilsvarende elektrisk modstand, uden at forøge den termiske masse af nævnte varmeveksler.

4. Anordning til at generere tåge (1) i henhold til patentkrav 1, kendetegnet ved at nævnte sektioner af rørformede dele (11, 12) er forbundet parallelt gennem delene (111, 112) fungerende som modstand, og i rækker gennem delene (112, 122) fungerende som væske overheder.

5. Anordning til at generere tåge (1) i henhold til patentkrav 1, kendetegnet ved at nævnte sektioner af rørformede dele (11, 12) er forbundne i rækker gennem delene (111, 112) fungerende som modstand, og i rækker gennem delene (112, 122) fungerende som væske overheder.

6. Anordning til at generere tåge (1) i henhold til et af foregående patentkrav, kendetegnet ved at hver af nævnte sektioner af rørformede dele (11, 12) er elektrisk forbundne til en akkumulator (60), nævnte akkumulator (60) er af en elektrokemisk type, og ved at nævnte kontrolenhed (41, 42) fremviser et estimat af den af nævnte akkumulator (60) leverede strøm, estimatet bliver beregnet af værdien af spændingsfaldet målt i mindst den ene del (111, 121) for at godtgøre status i nævnte akkumulator (60), i form af elektrisk ladning, driftsfald på grund af aldring, mulig brug for en udskiftning.

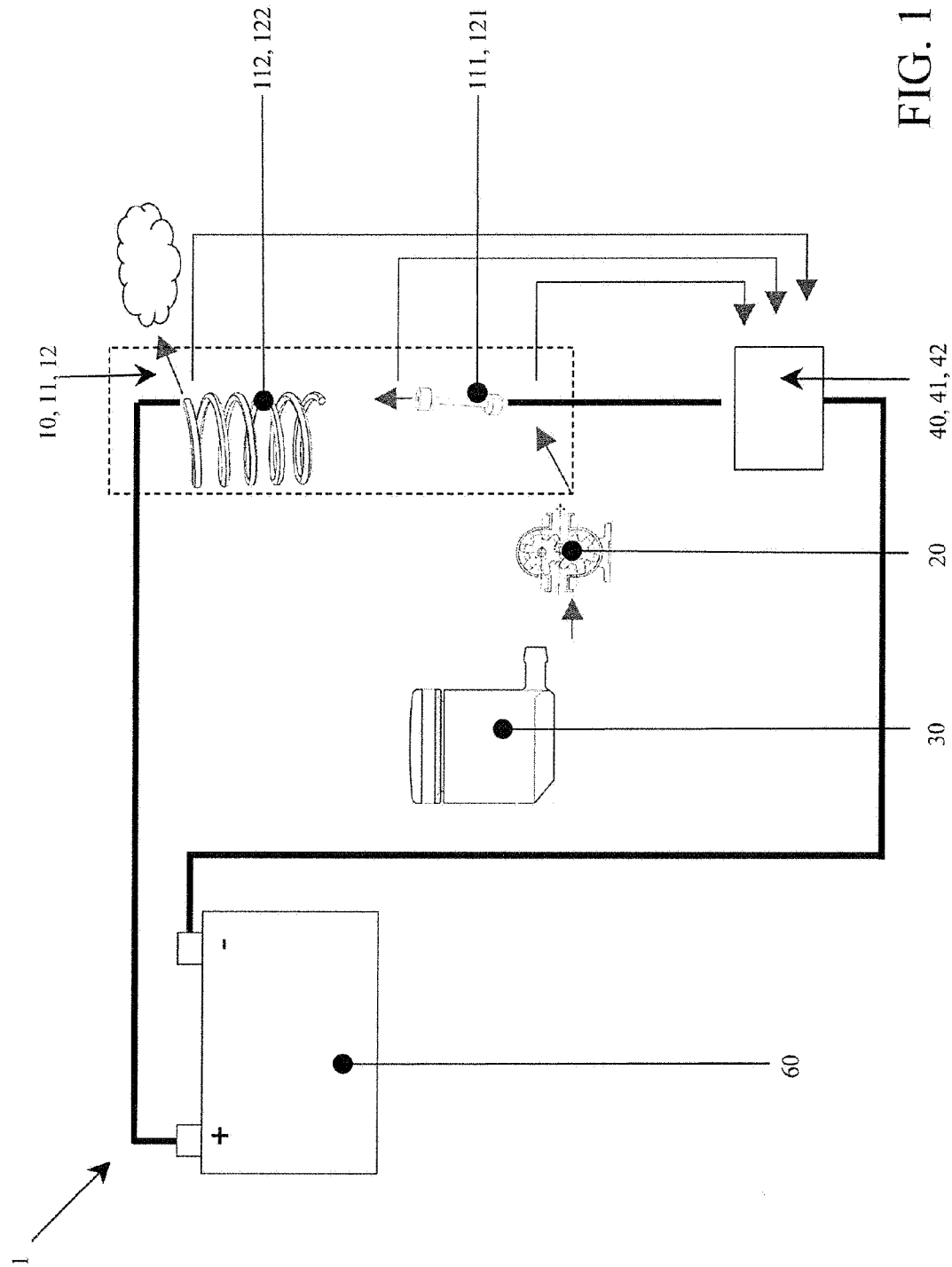
7. Anordning til at generere tåge (1) i henhold til patentkrav 1, kendetegnet ved at nævnte mindst ene del (111, 121) er afkølet af væsken som cirkulerer i anordningen (1).

8. Driftsmetode til at optimere opvarmnings tider og maksimere termisk kraft overført til en væske i en anordning til at generere tåge (1) i henhold til et af foregående patentkrav, kendetegnet ved at den omfatter følgende trin:

- tør opvarmning af varmeveksleren (10);
- kontrolleret start af tryksættende midler (20) for at sende væske langs et par sektioner af rørformede dele (11, 12) af de rørformede elementer, indtil en temperatur målt i mindst den ene af nævnte sektioner af rørformede dele (11, 12) begynder at falde;
- kontrol af driften af de tryksættende midler (20) gennem

en måling af en elektrisk potentiel difference i de rørformede elementer, for at holde temperaturen konstant i sektionerne af rørformede dele (11, 12) af nævnte par af sektioner af rørformede dele (11, 12) som afkøler først for at opnå den maksimalt opnåelige strøm.

# DRAWINGS



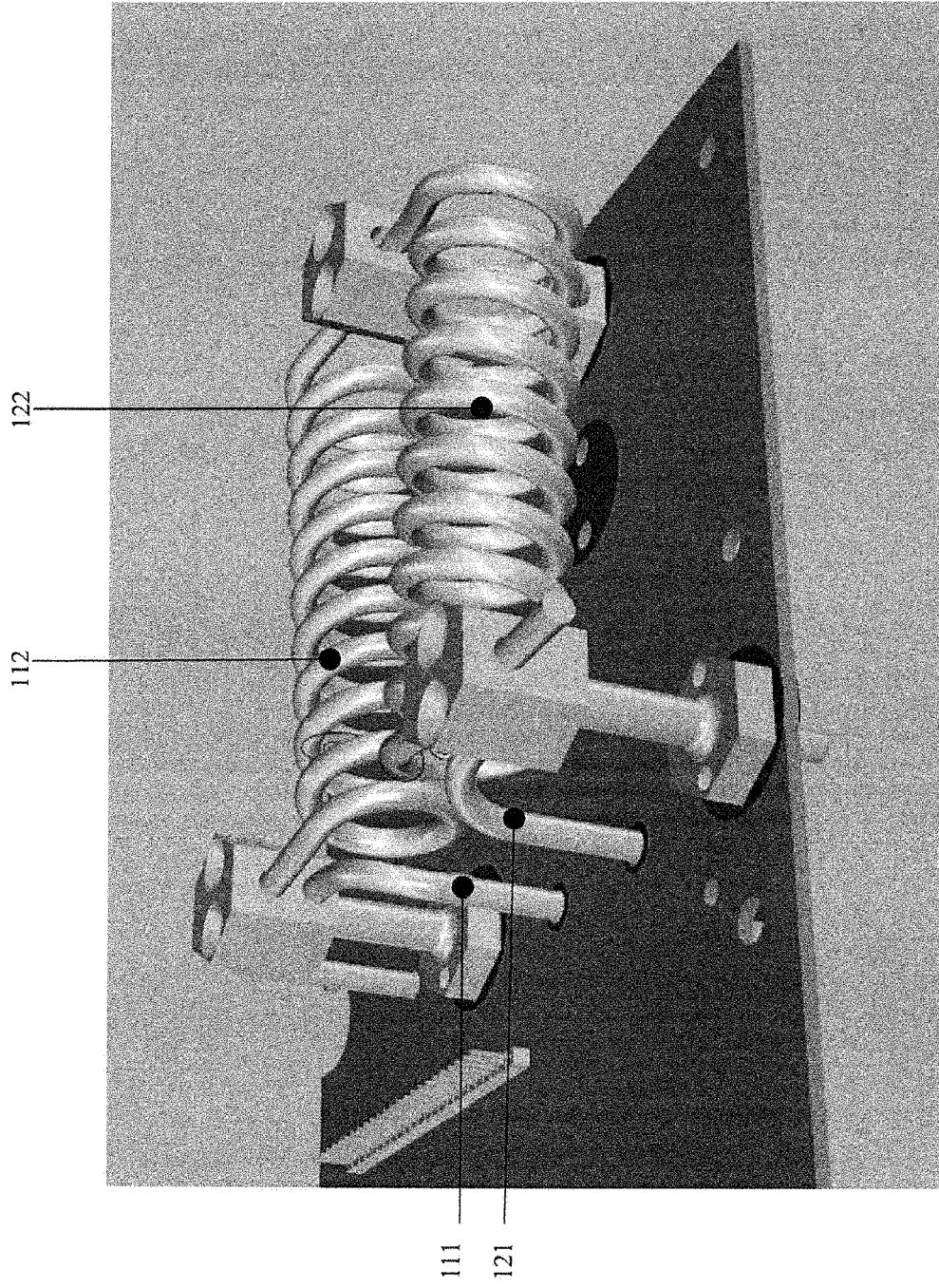
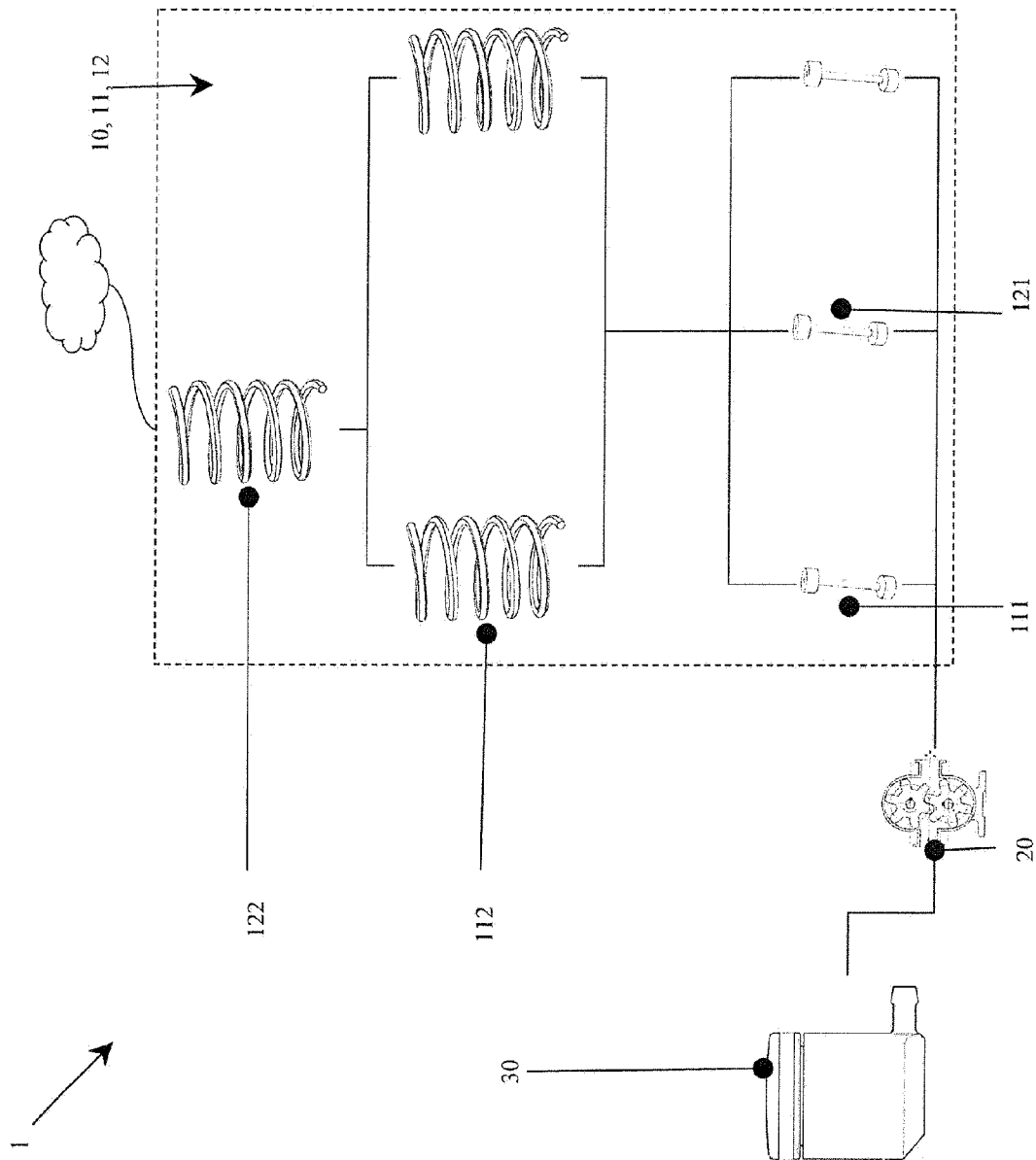


FIG. 2

FIG. 3



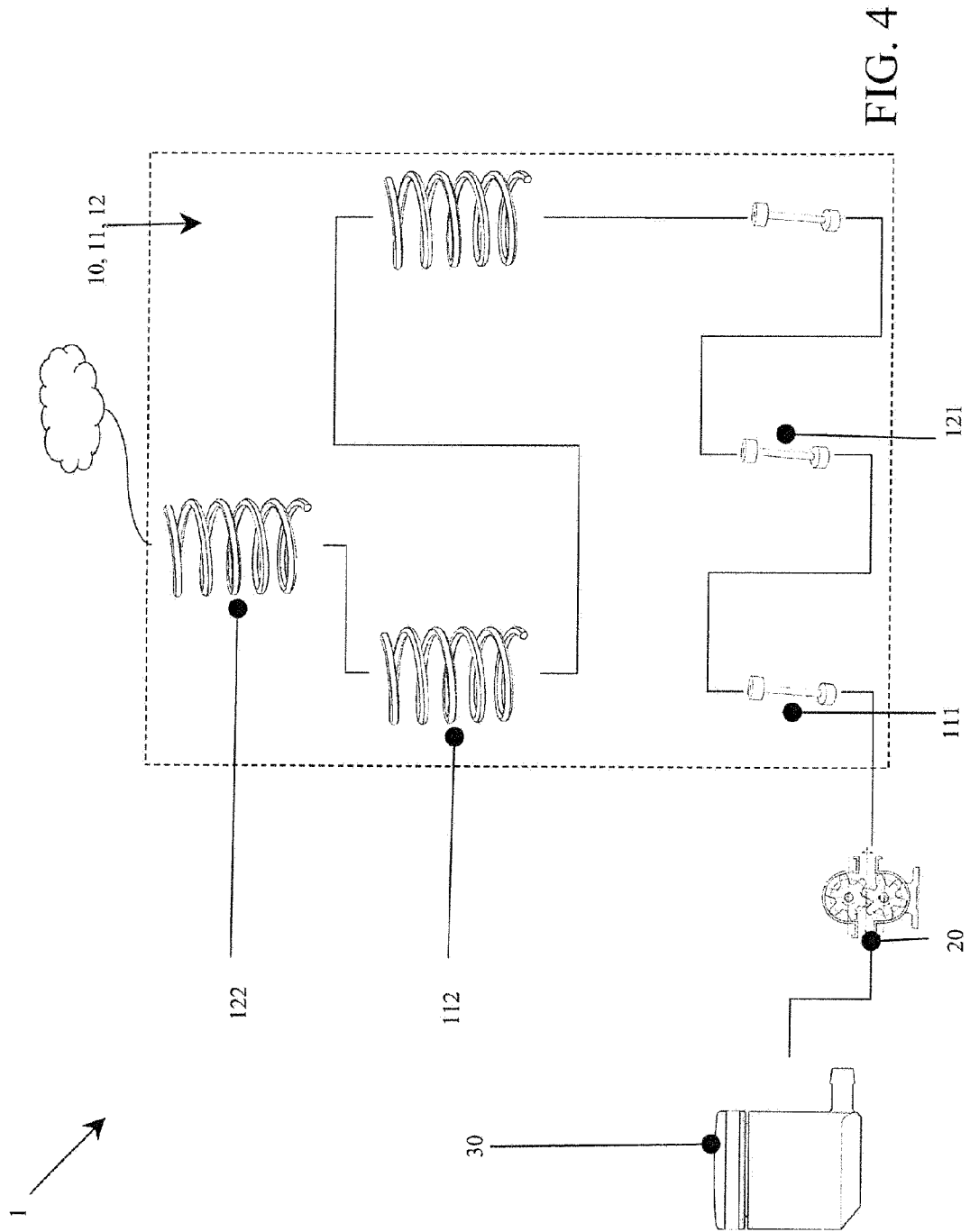
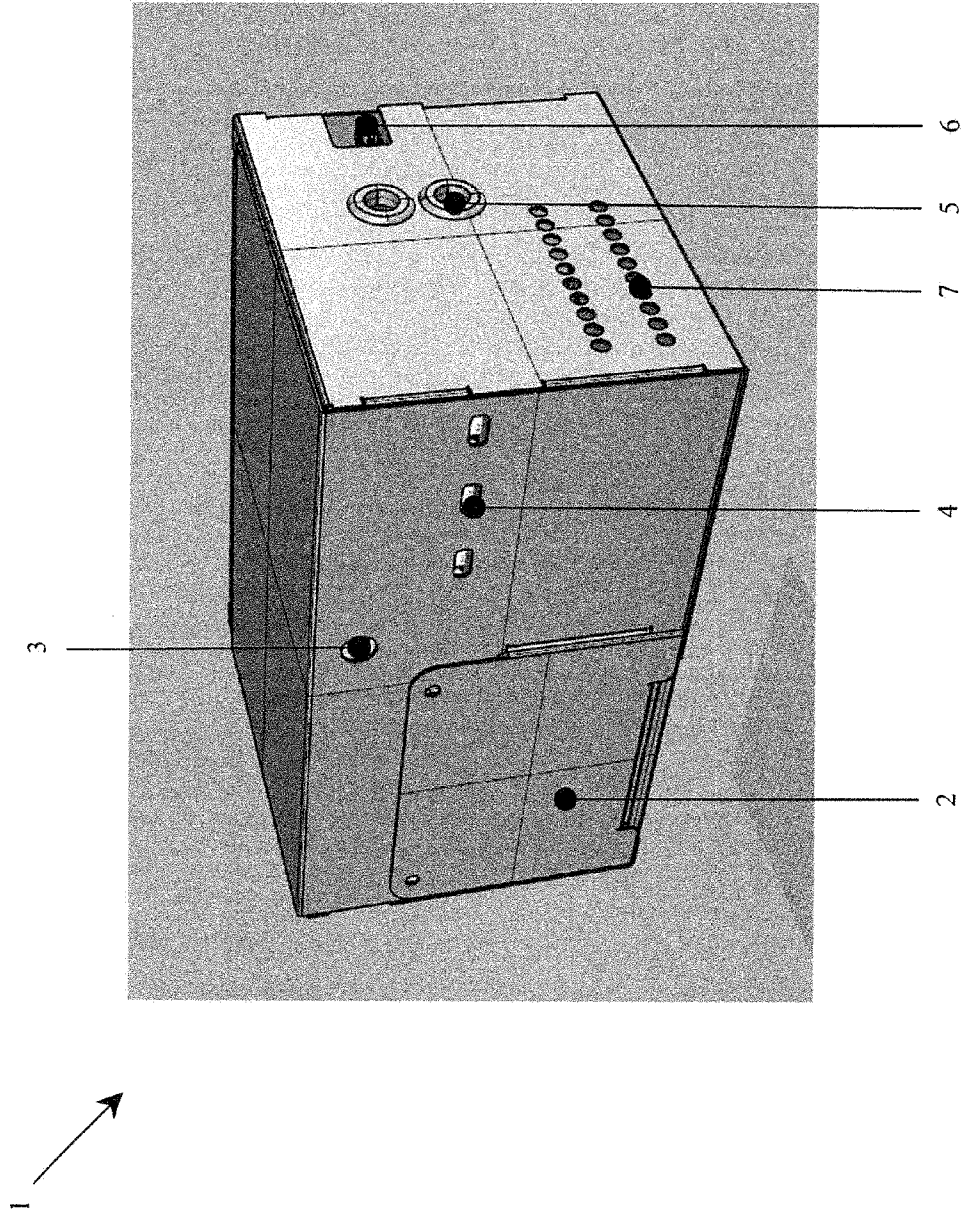


FIG. 4

FIG. 5



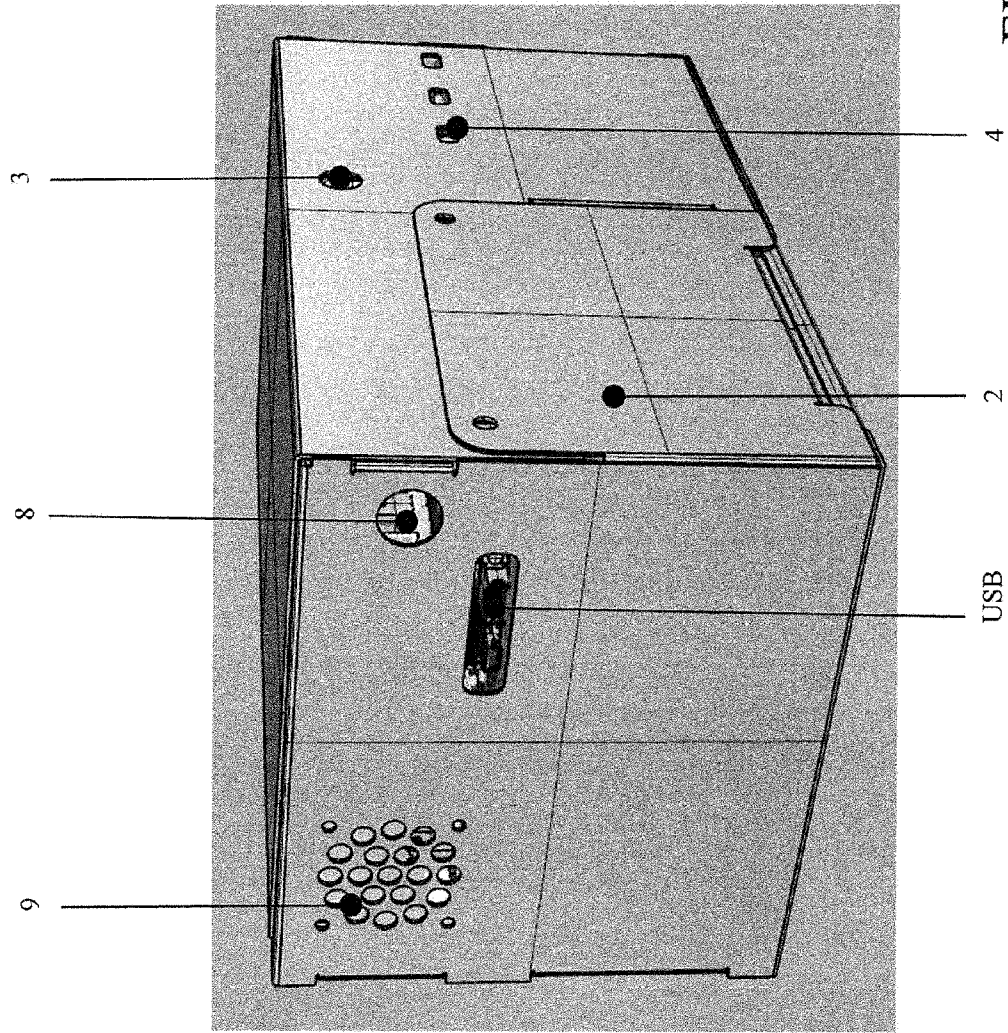


FIG. 6