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EPC.

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(54) **Defrosting**

(57) An apparatus comprising a cooling chamber comprising a cooling unit for cooling uranium hexafluoride in the chamber; and a heater comprising a first region inside the cooling chamber arranged to defrost the cooling unit; and a second region outside the cooling chamber

arranged to receive heating fluid cooled in the first region and to heat the received fluid. A method of defrosting a cooling unit is also described.

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Description

Field

[0001] The invention relates to defrosting a cooling chamber. Particularly, but not exclusively, the invention relates to defrosting a cooling unit in a uranium hexafluoride cooling chamber using a fluid which is heated outside the cooling chamber.

Background

[0002] In cooling chambers for cooling uranium hexafluoride, a cooling unit such as a cooling evaporator can be used to cool the chamber as part of a vapour compression cycle. However, ice formed on the surface of the cooling evaporator may inhibit the operation of the evaporator.

Summary

[0003] According to the invention, there is provided an apparatus comprising: a cooling chamber comprising a cooling unit for cooling uranium hexafluoride in the chamber; and a heater comprising a first region inside the cooling chamber arranged to defrost the cooling unit and a second region outside the cooling chamber arranged to receive heating fluid cooled in the first region and to heat the received fluid.

[0004] The first region of the heater may be arranged to receive fluid heated in the second region of the heater.

[0005] The first region of the heater may be configured to heat the cooling unit by exposing the cooling unit to a first region of heating fluid conduit containing fluid heated in the second region of the heater.

[0006] The second region of the heater may be configured to heat the fluid cooled in the first region by exposing the fluid to an ambient temperature fluid outside the cooling chamber.

[0007] The ambient temperature may be between approximately fifteen and thirty degrees Celsius.

[0008] The second region of the heater may comprise a heat exchanger configured to move ambient temperature fluid outside the cooling chamber over the second region of the heater.

[0009] The ambient temperature fluid outside the cooling chamber may be atmospheric air.

[0010] The heater may comprise a heating fluid circuit comprising said first and second regions.

[0011] The second region of the heater may comprise a second region of heating fluid conduit which is exposed to ambient temperature fluid outside the cooling chamber and is arranged to receive the fluid cooled in the first region of the heater.

[0012] The second region of heating fluid conduit may comprise one or more heat exchange elements to increase the effective surface area of the second region of conduit which is exposed to the ambient temperature fluid

outside the cooling chamber.

[0013] The cooling unit may comprise a cooling evaporator configured to evaporate a fluid coolant.

[0014] The cooling chamber may be configured to receive a uranium hexafluoride container.

[0015] The cooling unit may be configured to cool the chamber to a temperature of below zero degrees Celsius.

[0016] According to the invention, there is provided an apparatus for defrosting a cooling unit in a uranium hexafluoride cooling chamber, comprising: a first heat exchanger configured to heat the cooling unit by exposing the cooling unit to a first region of heating fluid conduit inside the cooling chamber; and a second heat exchanger configured to heat the heating fluid by exposing a second region of heating fluid conduit to an ambient temperature outside the cooling chamber.

[0017] According to the invention, there is provided a method of defrosting a cooling unit for cooling uranium hexafluoride in a cooling chamber, comprising: causing a heating fluid to flow into the cooling chamber; causing the heating fluid to heat the cooling unit in the cooling chamber, thereby cooling the heating fluid; causing the heating fluid to flow out of the cooling chamber; and causing the heating fluid to be heated outside the cooling chamber.

[0018] Causing the heating fluid to be heated outside the cooling chamber may comprise exposing the heating fluid to an ambient temperature outside the cooling chamber.

[0019] For exemplary purposes only, embodiments of the invention are described below with reference to the accompanying figures in which:

Brief description of the figures

[0020]

Figure 1 is a schematic illustration of a uranium hexafluoride take-off unit;

figure 2 is a schematic illustration of a cooling chamber for cooling uranium hexafluoride and a heating fluid circuit for defrosting an evaporator in the cooling chamber;

figure 3a is a schematic illustration of heat exchange region of a heating fluid circuit for causing defrosting inside a cooling chamber;

figure 3b is another schematic illustration of a heat exchange region of a heating fluid circuit for causing defrosting of inside a cooling chamber;

figure 4 is a cross-sectional illustration of a heat exchange conduit of a heating fluid circuit and an evaporator conduit of a cooling circuit;

figure 5 is a flow diagram of a defrosting process for defrosting an evaporator of a cooling circuit;

figure 6 is a schematic illustration of a heat exchanger for transferring heat energy from an ambient fluid around the heat exchanger to a heating fluid; and figure 7 is a schematic illustration of a heat exchange

region of a heating fluid circuit and a heat exchange region of a cooling fluid circuit, both regions being arranged to exchange heat with ambient fluid outside of a cooling chamber.

Detailed description

[0021] Referring to figure 1, a uranium hexafluoride (UF_6) take-off unit 1 is configured to deliver uranium hexafluoride from a uranium hexafluoride source 2 to a uranium hexafluoride container 3. The source 2 may be any source of gaseous uranium hexafluoride. For example, the source 2 may comprise a cascade of gas centrifuges configured to separate uranium-235 isotope from uranium-238 isotope. The uranium hexafluoride container 3 may be substantially cylindrical in shape and is manufactured according to International standards.

[0022] The take-off unit 1 comprises an apparatus 4 for cooling the uranium hexafluoride container 3. As shown schematically in figure 2, the apparatus 4 includes a cooling chamber 5 configured to accommodate the container 3 and to cool the container 3 to a predetermined temperature. The cooling chamber 5 may be thermally insulated to limit heat transfer through exterior walls 6 of the chamber 5. For example, the walls 6 of the cooling chamber 5 may comprise one or more layers of thermal insulation 7. The container 3 can be inserted into and removed from the chamber 5 through a closable opening 8 of the chamber 5 as required. The opening 8 can, for example, comprise a door 8a which when closed is configured to seal the opening 8 in the chamber 5 and when open allows the container 3 to be replaced.

[0023] A uranium hexafluoride conduit 9 is configured to channel gaseous uranium hexafluoride from the uranium hexafluoride source 2 to the container 3 inside the cooling chamber 5. The conduit 9 may be a pipe, as shown in figures 1 and 2. An entry of the conduit 9 is connected to the uranium hexafluoride source 2 to receive uranium hexafluoride. An exit of the conduit 9, through which uranium hexafluoride is selectively output, is connectable to an entry of the container 3 when the container 3 is inside the cooling chamber 5. The conduit 9 may be trace heated by a suitable heater to ensure that uranium hexafluoride inside the conduit 9 remains in a gaseous state. For example, a low power electrical heater (not shown) may be configured to trace heat the conduit 9 to maintain a suitable temperature. The heater may, for example, be configured to trace heat the conduit 9 to temperatures of between approximately forty and sixty degrees Celsius. An example temperature is approximately fifty degrees Celsius.

[0024] The exit of the uranium hexafluoride conduit 9 may comprise a connector 9a. The connector 9a is located inside the cooling chamber 5 and is configured to connect an entrance of the uranium hexafluoride container 3 to the exit of the conduit 9 so that uranium hexafluoride can flow through the conduit 9 from the source 2 into the container 3. The connector 9a comprises a

valve 9b which is configured to control the rate of flow of the uranium hexafluoride into the container 3. The valve 9b can be actuated to selectively increase, decrease or stop the flow rate of uranium hexafluoride through the exit of the conduit 9. The connector 9a may also comprise a suitable seal to seal the connection between the conduit 9 and the container 3.

[0025] As schematically illustrated in figure 2, the apparatus 4 comprises a cooling circuit 10 for cooling the interior of the cooling chamber 5. The cooling circuit 10 comprises a closed loop system through which a fluid coolant 11 such as Freon is caused to flow in a re-circulating fashion to remove heat from the cooling chamber 5. As described below, the cooling circuit 10 may be configured to implement a vapour compression cycle to cool the chamber 5.

[0026] The cooling circuit 10 comprises a first region outside the cooling chamber 5 and a second region inside the cooling chamber 5. During a complete cycle around the circuit 10, the coolant 11 flows through the first region and the second region in sequence so that the coolant 11 flows into, and back out of, the cooling chamber 5.

[0027] The first region of the cooling circuit 10, located outside the cooling chamber 5, comprises a compressor 12 configured to compress the coolant 11, a condenser 14 configured to condense the coolant 11 and an expansion valve 15 configured to expand the coolant 11. The first region of the cooling circuit 10 may also comprise a pump 13 configured to pump the coolant 11 through the circuit 10.

[0028] The second region of the cooling circuit 10, located inside the cooling chamber 5, comprises a cooling unit 16 which is configured to cool the interior of the cooling chamber 5. The cooling unit 16 will be described below in terms of a cooling evaporator 16 which is configured to evaporate the coolant 11 and thereby extract heat energy from a fluid, such as air, inside the cooling chamber 5. The evaporator 16 may comprise an evaporator coil. However, other types of cooling unit 16 may alternatively be used. An example operation of the cooling circuit 10 is briefly described below with respect to figure 2.

[0029] In a first stage of the cooling cycle, coolant vapour 1] is compressed by the compressor 12 located outside of the cooling chamber 5 to cause heating and an increase in pressure of the coolant vapour 11. At a second stage, the compressed vapour 11 moves from the compressor 12 to the condenser 14 where the coolant 11 loses heat energy and condenses. At a third stage of the cycle, the condensed coolant 11 flows through the expansion valve 15 into the evaporator 16 located inside the cooling chamber 5. In the evaporator 16, the coolant 11 is converted to vapour and thereby cools the cooling chamber 5 by extracting heat energy from the fluid surrounding the evaporator 16 inside the chamber 5. Fluid inside the cooling chamber 5 can optionally be blown over the evaporator 16 by a fan 17 during the cooling cycle to increase the rate of cooling in the chamber 5. In

a fourth stage of the cycle, the coolant vapour 11 exits the cooling unit 16 and cooling chamber 5. In a fifth stage of the cycle, the coolant 11 returns to the compressor 12 to be recirculated around the cooling circuit 10 in the manner described above. When the cooling chamber 5 contains a uranium hexafluoride container 3, the cooled fluid inside the cooling chamber 5 causes a corresponding cooling of the container 3.

[0030] The cooling circuit 10 is configured to control the temperature inside the cooling chamber 5. More particularly, the cooling circuit 10 may be configured to selectively decrease or maintain the temperature inside the cooling chamber 5 based on suitable control signals. The rate of cooling in the chamber 5 may be varied by providing appropriate control signals to the compressor 12. For example, the apparatus 4 may comprise a control unit 18 which is configured to control the operation of the compressor 12 and vapour compression cycle in the cooling circuit 10. The control unit 18 is configured to receive temperature signals from a temperature monitoring unit 19, which is configured to measure the temperature inside the cooling chamber 5, and to provide appropriate control signals to the compressor 12 to cause the required increase or decrease in the cooling rate. In this way, the control unit 18 is able to increase or decrease the rate of cooling to maintain or achieve a particular temperature inside the cooling chamber 5.

[0031] Under the control of the control unit 18, the cooling circuit 10 may be configured to cool the cooling chamber 5 and container 3 therein to a predetermined temperature and, thereafter, to maintain the predetermined temperature in the cooling chamber 5 and container 3. Optionally, maintaining the predetermined temperature may comprise maintaining the temperature within a particular temperature range either side of the predetermined temperature. The predetermined temperature may be lower than the ambient temperature outside of the cooling chamber 5. An example is minus thirty degrees Celsius, although other temperatures, such as any temperature between zero degrees Celsius and minus seventy degrees Celsius, can alternatively be obtained as required. Optionally, the predetermined temperature is selected by a user by inputting an instruction to the apparatus 4. The apparatus 4 may comprise a control panel or any other suitable means (not shown) for inputting the instruction. The predetermined temperature may cause gaseous uranium hexafluoride entering the container 3 from the uranium hexafluoride conduit 9 to solidify inside the container 3.

[0032] The vapour compression cycle in the cooling circuit 10 can cause ice to be formed on one or more exterior surfaces of the evaporator 16. The formation of ice on the evaporator 16 is not desirable because it can decrease the cooling effect of the cooling circuit 10. For example, ice on the exterior of the evaporator 16 can reduce the efficiency with which heat energy is transferred between the coolant 11 in the circuit 10 and the fluid inside the cooling chamber 5.

[0033] Referring again to figure 2, the apparatus 4 comprises a heating circuit 20 configured to defrost the external surface of the evaporator 16. In a similar manner to the cooling circuit 10, the heating circuit 20 comprises a closed loop system through which a heating fluid 21 such as ethylene glycol or a mixture of ethylene glycol and water is selectively caused to flow into and out of the cooling chamber 5. A pump 22 may be configured to circulate the heating fluid 21 through the circuit 20. As shown in figure 2, the circuit 20 comprises at least one heating fluid conduit such as at least one pipe or any other means suitable for channelling the heating fluid 21 around the circuit 20.

[0034] The heating circuit 20 comprises a first region inside the cooling chamber 5 and a second region outside the cooling chamber 5. The first region is configured to transfer heat energy from the heating fluid 21 to the evaporator 16 to defrost the evaporator 16, whilst the second region is configured to transfer heat energy from the ambient heat energy outside the cooling chamber 5 to the heating fluid 21. In this way, the second region of the heating circuit 20 is configured to re-heat heating fluid 21 received from the first region of the heating circuit 20. The re-heated heating fluid 21 flows from the second region of the heating circuit 20 back into the first region of the heating circuit 20 to further defrost the evaporator 16.

[0035] The first region of the heating circuit 20 may comprise a first heat exchange region 23. The first heat exchange region 23 is located inside the cooling chamber 5 and is configured to transfer heat from the heating fluid 21 to the evaporator 16 to cause defrosting of the evaporator 16. An example of the first heat exchange region 23 is illustrated in figures 3a and 3b. As can be seen from figure 3a and 3b, the first heat exchange region 23 may comprise one or more heating fluid conduits 23a which are located adjacent to the evaporator 16. The geometrical shape of the first heat exchange region 23 is such that it fits closely with the evaporator 16. For example, the first heat exchange region 23 and the evaporator 16 may be comprise within the same heat exchange unit. In this case the evaporator 16 comprises a first channel for directing the cooling fluid 11 and the heating fluid conduits 23a comprise a second channel for directing the heating fluid 21. This is evident from the example shown in figures 3a and 3b, in which the heating fluid conduits 23a of the first heat exchange region 23 are positioned close to the external surfaces of the evaporator 16. The close geometrical relationship between the first heat exchange region 23 and the evaporator 16 increases the efficiency with which heat is transferred from the heating fluid 21 in the heat exchange region 23 to the evaporator 16.

[0036] Optionally, the first heat exchange region 23 may comprise a subsidiary heating unit such as a subsidiary heating fluid loop, or other heat exchange unit, inside the cooling chamber 5. The subsidiary heating unit is arranged to receive heat from the heating fluid 21 in the main portion of the heating circuit 20 inside the cooling

chamber 5 and to supply the heat to the evaporator 16.

[0037] As shown in figure 3a, the external surface of the first heat exchange region 23 may comprise one or more projecting heat transfer elements 23b, such as fins or other heat-conductive elements on the surfaces of one or more of the heating fluid conduits 23a, to increase the external surface area of the heat exchange region 23 and thereby increase the rate at which the first heat exchange region 23 transfers heat to the evaporator 16 via the intermediate fluid in the chamber 5. The heat transfer elements 23b are formed of a suitable heat conductive material such as aluminium. The heat transfer elements 23b are omitted from figure 3b for reasons of clarity of the figure. However, it will be appreciated that the heat transfer elements 23b could nevertheless be included.

[0038] Alternatively, as illustrated in figure 4, the one or more heating fluid conduits 23a of the first heat exchange section 23 may abut the external surface of the evaporator 16 so that heat from the heating fluid 21 is transferred directly to the evaporator 16. Optionally, the heating fluid conduits 23a of the first heat exchanger 23 may share a common wall 23c with the evaporator 16.

[0039] The second region of the heating circuit 20 comprises a second heat exchange region 24. The second heat exchange region 24 is located outside the cooling chamber 5 and comprises at least one heating fluid conduit 24a which is arranged to receive heating fluid 21 from the first region of the heating circuit 20. This received heating fluid 21 has been cooled in the first region of the heating circuit 20 during the process of heating the evaporator 16 described above. The second heat exchange section 24 is exposed to ambient environmental conditions including ambient temperature and pressure outside the cooling chamber 5 and is configured to heat the received heating fluid 21 using heat extracted from ambient temperature fluid outside the chamber 5. The ambient temperature is preferably above zero degrees Celsius and may be between approximately five and thirty-five degrees. An example is a temperature of between approximately fifteen and twenty-five degrees Celsius. The ambient pressure may be atmospheric pressure. An example is approximately 101.325 kPa. The ambient environmental conditions outside the cooling chamber 5 may be those which are naturally present in the room or hall in which the take-off station 1 is located.

[0040] In more detail, the heating fluid conduit(s) 24a in the second heat exchange region 24, may be exposed to the ambient temperature fluid, such as atmospheric air, outside the cooling chamber 5. Therefore, if the ambient temperature of the fluid outside the chamber 5 is greater than the temperature of the heating fluid 21 inside the second heat exchange region 24, the heating fluid 21 inside the second heat exchange region 24 is naturally heated by the ambient temperature fluid outside the chamber 5. In this way, heating fluid 21 which has lost heat energy by heating the evaporator 16 in the cooling chamber 5 re-gains the lost heat energy from the ambient heat energy in the fluid outside of the cooling chamber

5. The heating process is shown in figure 5 and described below in terms of a complete cycle of the heating fluid 21 around the heating circuit 20. The ambient fluid outside the cooling chamber 5 does not need to comprise atmospheric air and may alternatively comprise another gas, or a liquid such as water.

[0041] Referring to figure 5, a first stage S1 of the heating cycle comprises de-activating the cooling circuit 10 so that cooling fluid 11 does not flow inside the cooling chamber 5. A second stage S2 of the heating cycle comprises de-activating the fan 17, described above with respect to the cooling cycle, for the duration of the heating cycle. This prevents undesired movement of the internal fluid in the chamber 5.

In a third stage S3 of the heating cycle, heating fluid 21 is caused to flow through the heating fluid circuit 20 from the exterior of the cooling chamber 5 to the interior of the cooling chamber 5. For example, as with the cooling circuit 10 described previously, a fluid conduit of the heating circuit 20 may pass through a thermally-insulated entrance in a wall 6 of the cooling chamber 5. The temperature of the heating fluid 21 upon entering the cooling chamber 5 is greater than the temperature of the interior of the cooling chamber 5. In a fourth stage S4, the heating fluid 21 enters the first heat exchange region 23 of the circuit 20. Due to the temperature difference between the heating fluid 21 and the external surface of the evaporator 16 in the cooling chamber 5, heat energy is transferred from the heating fluid 21 in the heat exchange section 23 to the evaporator 16. The transfer of heat energy may occur either directly or via an internal fluid, such as air, inside the cooling chamber 5 in the manner as previously described. The transfer of heat energy from the heating fluid 21 raises the temperature of the evaporator 16 and reduces the temperature of the heating fluid 21. The increase in temperature of the evaporator 16 defrosts the exterior of the evaporator 16.

[0042] In a fifth stage S5 of the heating cycle, the cooled heating fluid 21 flows out of the cooling chamber 5 and into the second region of the heating circuit 20. For example, the heating fluid 21 may flow through a heating fluid conduit which passes through a thermally-insulated exit in a wall 6 of the cooling chamber 5. In a sixth stage S6 of the heating cycle, the heating fluid 21 flows into the second heat exchange region 24. As referred to above, in the second heat exchange section 24 the heating fluid 21 is heated by the ambient temperature fluid outside the cooling chamber 5. More specifically, heat energy naturally flows from the ambient fluid outside the cooling chamber 5 to the heating fluid 21 inside the heating circuit 20 due to the temperature of the ambient fluid outside the cooling chamber 5 being greater than the temperature of the heating fluid 21 exiting the cooling chamber 5. The transfer of energy from the ambient fluid outside the cooling chamber 5 to the heating fluid 21 raises the temperature of the heating fluid 21 above the temperature inside the cooling chamber 5. In a seventh stage S7 of the heating cycle, the re-heated heating fluid 21 exits

the second heat exchange region 24 to complete the cycle. The heating fluid 21 can then re-enter the cooling chamber 5, as described above (see the third stage S3), where it is received by the first heat exchange region 23 to further heat and defrost the evaporator 16.

[0043] During activation of the heating circuit 20, steps S3 to S7 of the cycle may continue to occur in sequence until the evaporator 16 has been defrosted. Once the evaporator 16 has been adequately defrosted, the heating cycle is stopped in an eighth stage S8 by de-activation of the heating circuit 20. This is followed by reactivation of the cooling circuit 10 and fan 17 in ninth and tenth stages S9, S10 and a resumption of the cooling cycle.

[0044] The above-described steps S1 to S10 may be carried out under the control of the control unit 18. For example, the control unit 18 may comprise a processor which is configured to execute a computer program to cause the steps above to be carried out. The computer program may be stored in a memory of the control unit 18.

[0045] Referring to figure 6, one or more heating fluid conduits 24a of the second heat exchange region 24 may comprise one or more projecting heat transfer elements 24b configured to increase the rate of heat energy transfer from the ambient temperature fluid around the second heat exchange region 24 into the heating fluid 21 inside the heating fluid conduit(s) 24a. The heat transfer elements 24b may comprise fins or other heat-conductive elements which are attached or integrally-formed with the external surface of the heating fluid conduit(s) 24a. The heat transfer elements 24b increase the external surface area of the second heat exchange region 24 which is exposed to ambient temperature fluid outside the cooling chamber 5, and thereby increase the rate at which the second heat exchange region 24 transfers heat to the heating fluid 21.

[0046] Optionally, the second heat exchange region 24 may include a fan 25 or other suitable means for moving the ambient fluid over the heating fluid conduit(s) in the second heat exchange region 24. Moving the relatively warm ambient fluid over the second heat exchange region 24 increases the rate at which heat energy is transferred to the heating fluid 21 and, thereby, increases the temperature gain of the heating fluid 21 in the second heat exchange region 24. Although not illustrated in figure 2, the fan 25 may also be used to move ambient temperature fluid over the condenser 14 of the cooling circuit 10 during the cooling cycle previously described. For example, referring to figure 7, the second heat exchange region 24 of the heating circuit 20 and the condenser 14 of the cooling circuit 10 may be adjacent or otherwise closely arranged with one another, or combined in a single unit, so that ambient fluid, such as air, outside the chamber 5 can be blown over the condenser 14 and the second heat exchange region 24 of the heating circuit by the fan 25. The cooling circuit 10 and heating circuit 20 are separately activated as described previously with respect to figure 5.

[0047] The temperature gain of the heating fluid 21 in

the second heat exchange section 24 occurs naturally due to the temperature difference between the heating fluid 21 and ambient temperature fluid outside the cooling chamber 5. The amount of the temperature gain is therefore limited by the ambient temperature outside the cooling chamber 5. Even if the heating fluid 21 were continually circulated around the heating circuit 20, the cooling chamber 5 and the uranium hexafluoride container 3 would not be heated significantly beyond the ambient temperature present outside the cooling chamber 5. The heating circuit 20 thereby provides an advantage over other potential methods of defrosting the cooling evaporator 16, such as the use of electrical heating, because it prevents overheating and possible rupture of the uranium hexafluoride container 3 in the cooling chamber 5.

[0048] The control unit 18 may be configured to activate the heating circuit 20 to defrost the evaporator 16 at regular intervals. For example, the control unit 18 may be configured to activate the heating circuit 20 for a defined period approximately once every twenty-four hours. Additionally or alternatively, the control unit 18 may be configured to activate the heating circuit 20 in response to an indication that ice has formed on the surface of the evaporator 16. Such an indication may be provided by a suitable sensor (not shown) inside the cooling chamber 5. Activation of the heating circuit 20 may comprise pumping the heating fluid 21 through the heating circuit 20 for a period which is sufficient to adequately defrost the evaporator 16. The duration of activation may be selected as required and may be varied in dependence of the ambient temperature outside the cooling chamber 5 and the amount of ice on the surface of the evaporator 16. An example duration is between approximately ten and approximately thirty minutes.

[0049] As described previously, during activation of the heating circuit 20 the cooling circuit 10 is de-activated so that the cooling fluid 11 does not circulate through the evaporator 16. The control unit 18 is configured to reactivate the cooling circuit 10 following de-activation of the heating circuit 20.

[0050] It will be appreciated that the alternatives described above can be used singly or in combination.

Claims

1. An apparatus comprising:

a cooling chamber comprising a cooling unit for cooling uranium hexafluoride in the chamber; and
a heater comprising a first region inside the cooling chamber arranged to defrost the cooling unit; and a second region outside the cooling chamber arranged to receive heating fluid cooled in the first region and to heat the received fluid.

2. An apparatus according to claim 1, wherein the first

region of the heater is arranged to receive fluid heated in the second region of the heater.

3. An apparatus according to claim 1 or 2, wherein the first region of the heater is configured to heat the cooling unit by exposing the cooling unit to a first region of heating fluid conduit containing fluid heated in the second region of the heater. 5
4. An apparatus according to any preceding claim, wherein the second region of the heater is configured to heat the fluid cooled in the first region by exposing the fluid to an ambient temperature fluid outside the cooling chamber. 10
5. An apparatus according to claim 4, wherein the ambient temperature is between approximately fifteen and thirty degrees Celsius. 15
6. An apparatus according to claim 4 or 5, wherein the second region of the heater comprises a heat exchanger configured to move ambient temperature fluid outside the cooling chamber over the second region of the heater. 20
7. An apparatus according to any of claims 4 to 6, wherein the ambient temperature fluid outside the cooling chamber is atmospheric air. 25
8. An apparatus according to any preceding claim, wherein the heater comprises a heating fluid circuit comprising said first and second regions. 30
9. An apparatus according to any preceding claim, wherein the second region of the heater comprises a second region of heating fluid conduit which is exposed to ambient temperature fluid outside the cooling chamber and is arranged to receive the fluid cooled in the first region of the heater. 35
10. An apparatus according to claim 9, wherein the second region of heating fluid conduit comprises one or more heat exchange elements to increase the effective surface area of the second region of conduit which is exposed to the ambient temperature fluid outside the cooling chamber. 40
11. An apparatus according to any preceding claim, wherein the cooling unit comprises a cooling evaporator configured to evaporate a fluid coolant. 45
12. An apparatus according to any preceding claim, wherein the cooling chamber is configured to receive a uranium hexafluoride container. 50
13. An apparatus according to any preceding claim, wherein the cooling unit is configured to cool the chamber to a temperature of below zero degrees 55

Celsius.

14. An apparatus for defrosting a cooling unit in a uranium hexafluoride cooling chamber, comprising:
 - a first heat exchanger configured to heat the cooling unit by exposing the cooling unit to a first region of heating fluid conduit inside the cooling chamber; and
 - a second heat exchanger configured to heat the heating fluid by exposing a second region of heating fluid conduit to an ambient temperature outside the cooling chamber.
15. A method of defrosting a cooling unit for cooling uranium hexafluoride in a cooling chamber, comprising:
 - causing a heating fluid to flow into the cooling chamber;
 - causing the heating fluid to heat the cooling unit in the cooling chamber, thereby cooling the heating fluid;
 - causing the heating fluid to flow out of the cooling chamber; and
 - causing the heating fluid to be heated outside the cooling chamber.
16. A method according to claim 15, wherein causing the heating fluid to be heated outside the cooling chamber comprises exposing the heating fluid to an ambient temperature outside the cooling chamber.

Amended claims in accordance with Rule 137(2) EPC.

1. An apparatus of a uranium hexafluoride take-off unit, comprising:
 - a uranium hexafluoride cooling chamber configured to receive a uranium hexafluoride container, the chamber comprising a cooling unit for cooling the uranium hexafluoride in the chamber; and
 - a heater comprising a first region inside the cooling chamber arranged to defrost the cooling unit; and a second region outside the cooling chamber arranged to receive heating fluid cooled in the first region and to heat the received fluid, wherein the second region of the heater is configured to heat the fluid cooled in the first region by exposing the fluid to an ambient temperature fluid outside the cooling chamber.
2. An apparatus according to claim 1, wherein the first region of the heater is arranged to receive fluid heated in the second region of the heater.

3. An apparatus according to claim 1 or 2, wherein the first region of the heater is configured to heat the cooling unit by exposing the cooling unit to a first region of heating fluid conduit containing fluid heated in the second region of the heater. 5
4. An apparatus according to any preceding claim, wherein the ambient temperature is between approximately fifteen and thirty degrees Celsius. 10
5. An apparatus according to any preceding claim, wherein the second region of the heater comprises a heat exchanger configured to move ambient temperature fluid outside the cooling chamber over the second region of the heater. 15
6. An apparatus according to any preceding claim, wherein the ambient temperature fluid outside the cooling chamber is atmospheric air. 20
7. An apparatus according to any preceding claim, wherein the heater comprises a heating fluid circuit comprising said first and second regions. 25
8. An apparatus according to any preceding claim, wherein the second region of the heater comprises a second region of heating fluid conduit which is exposed to ambient temperature fluid outside the cooling chamber and is arranged to receive the fluid cooled in the first region of the heater. 30
9. An apparatus according to claim 8, wherein the second region of heating fluid conduit comprises one or more heat exchange elements to increase the effective surface area of the second region of conduit which is exposed to the ambient temperature fluid outside the cooling chamber. 35
10. An apparatus according to any preceding claim, wherein the cooling unit comprises a cooling evaporator configured to evaporate a fluid coolant. 40
11. An apparatus according to any preceding claim, wherein the cooling unit is configured to cool the chamber to a temperature of below zero degrees Celsius. 45
12. An apparatus according to claim 1, wherein:
- the first region of the heater comprises a first heat exchanger configured to heat the cooling unit by exposing the cooling unit to a first region of heating fluid conduit inside the cooling chamber; and 50
- the second region of the heater comprises a second heat exchanger configured to heat the heating fluid by exposing a second region of heating fluid conduit to an ambient temperature outside 55

the cooling chamber.

13. A method of defrosting a cooling unit in a uranium hexafluoride cooling chamber of a uranium hexafluoride take-off unit, comprising:

causing a heating fluid to flow into the cooling chamber;
causing the heating fluid to heat the cooling unit in the cooling chamber, thereby cooling the heating fluid;
causing the heating fluid to flow out of the cooling chamber; and
causing the heating fluid to be heated outside the cooling chamber by exposing the heating fluid to an ambient temperature outside the cooling chamber.

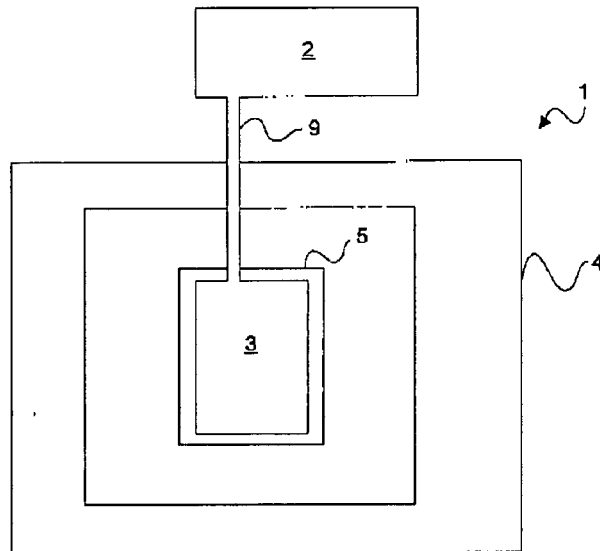


Fig. 1

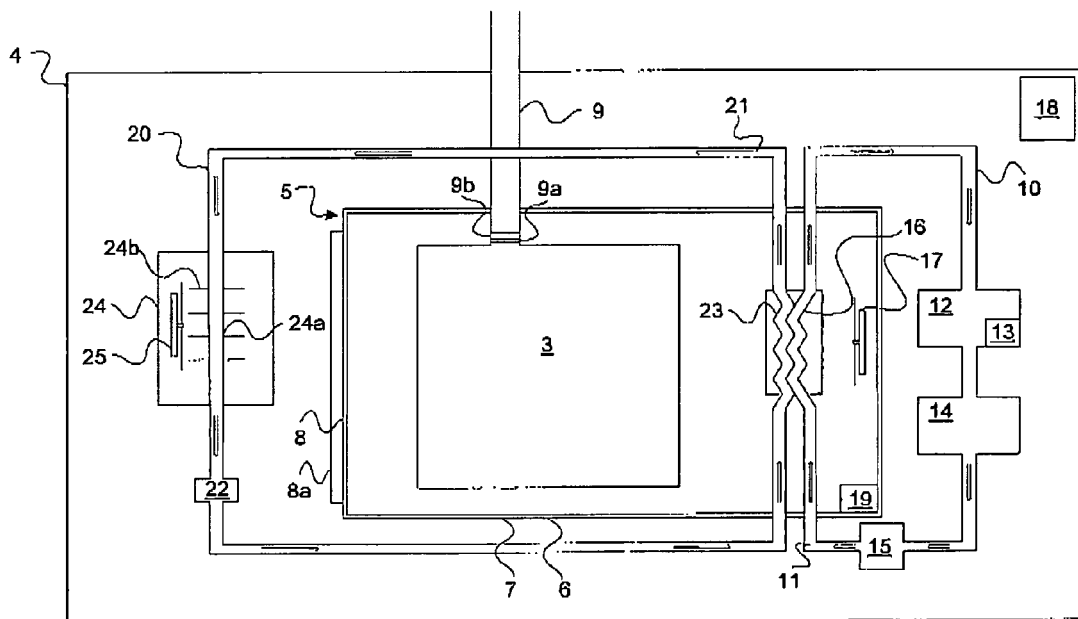


Fig. 2

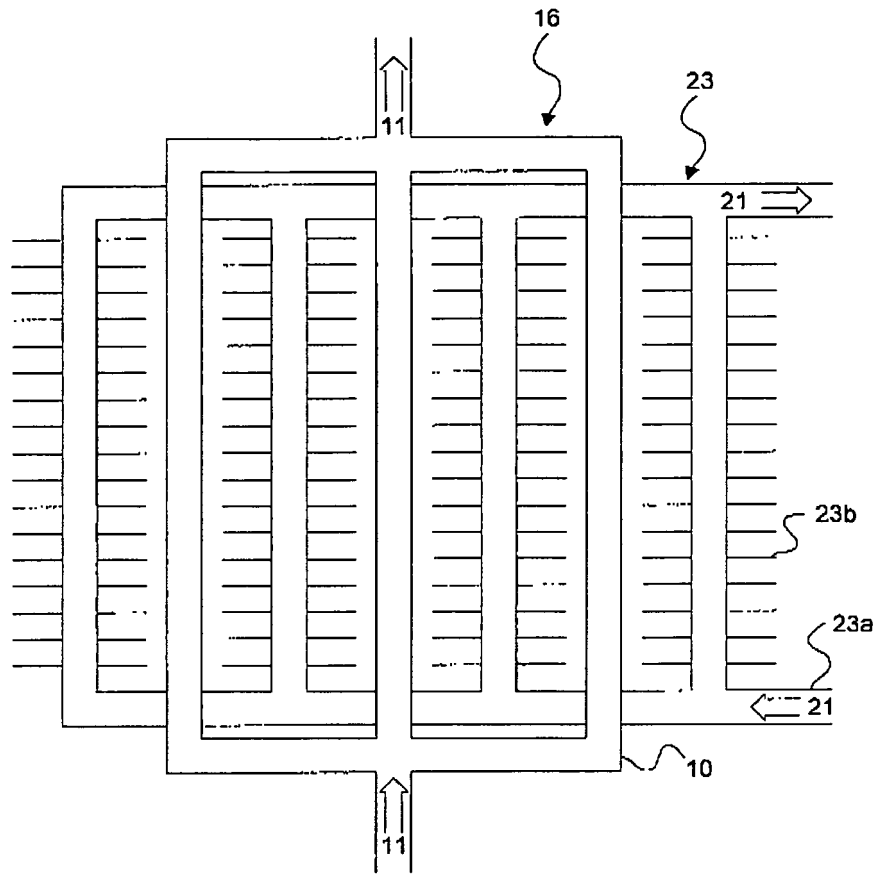


Fig. 3a

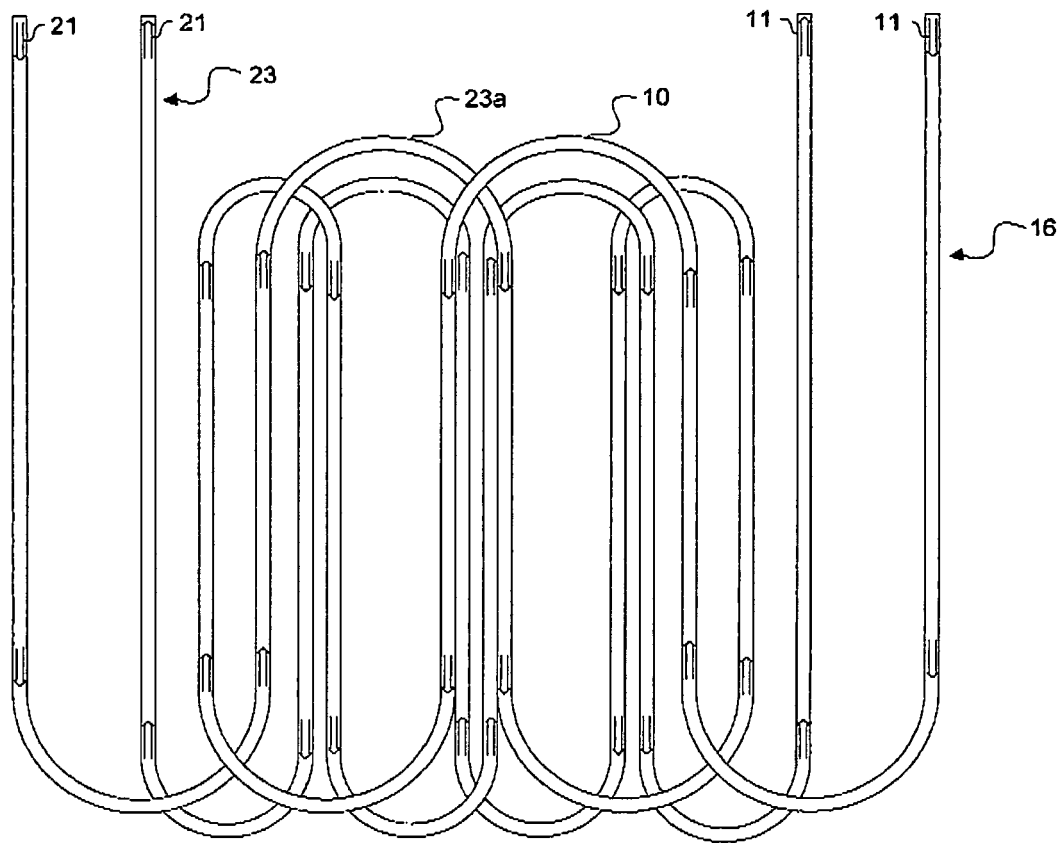


Fig. 3b

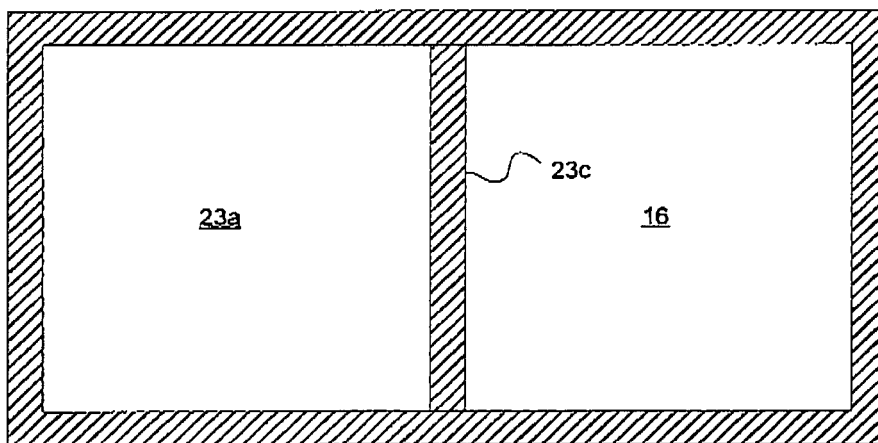


Fig. 4

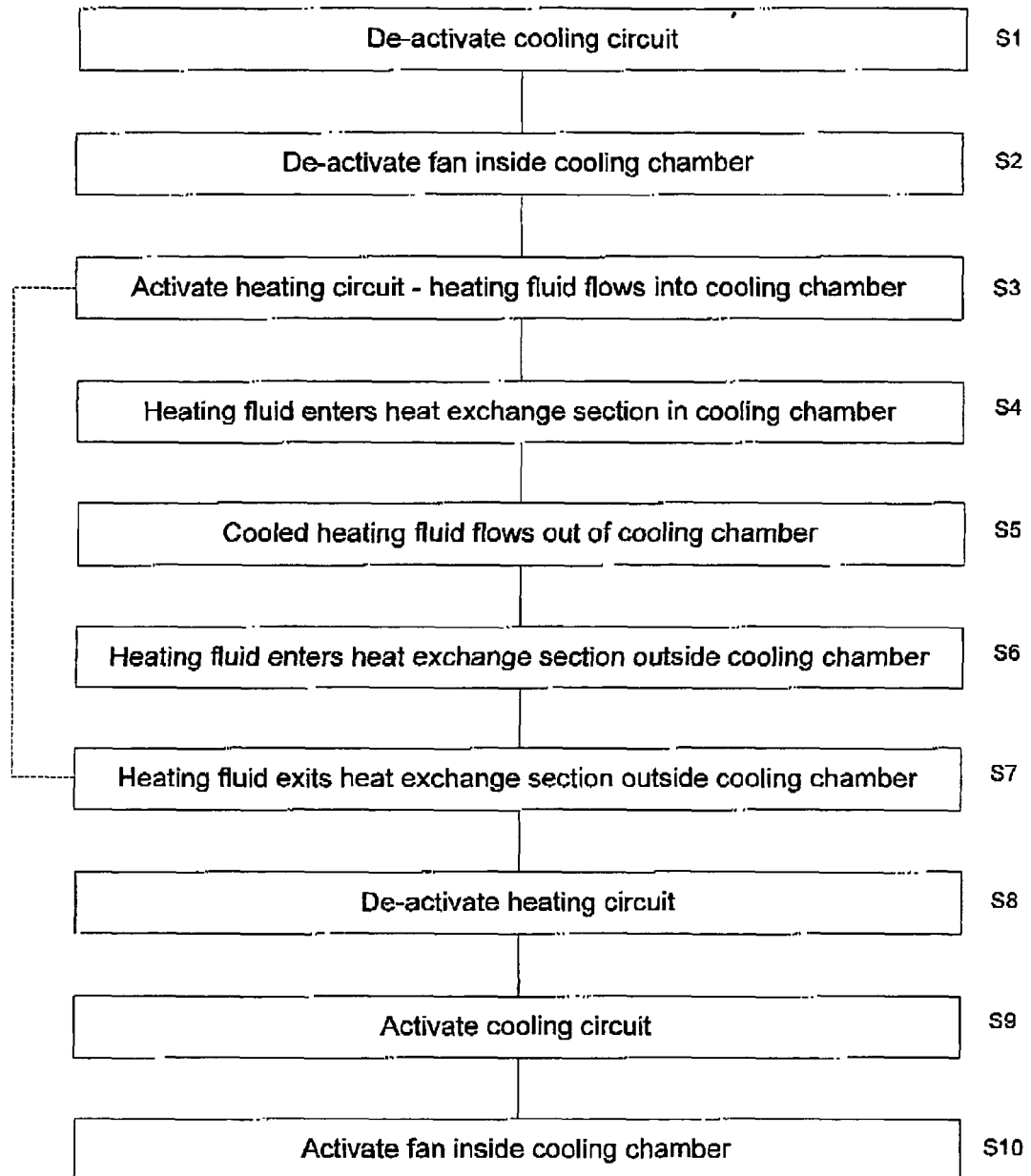


Fig. 5

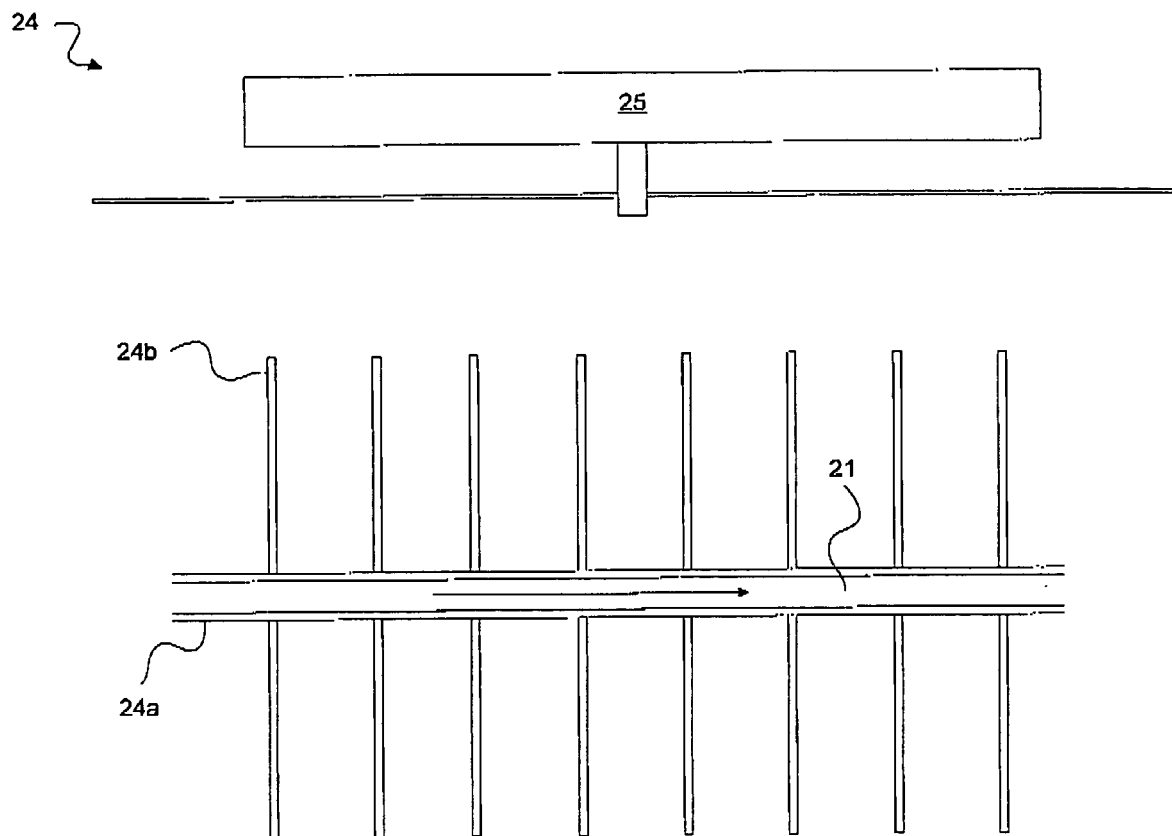


Fig. 6

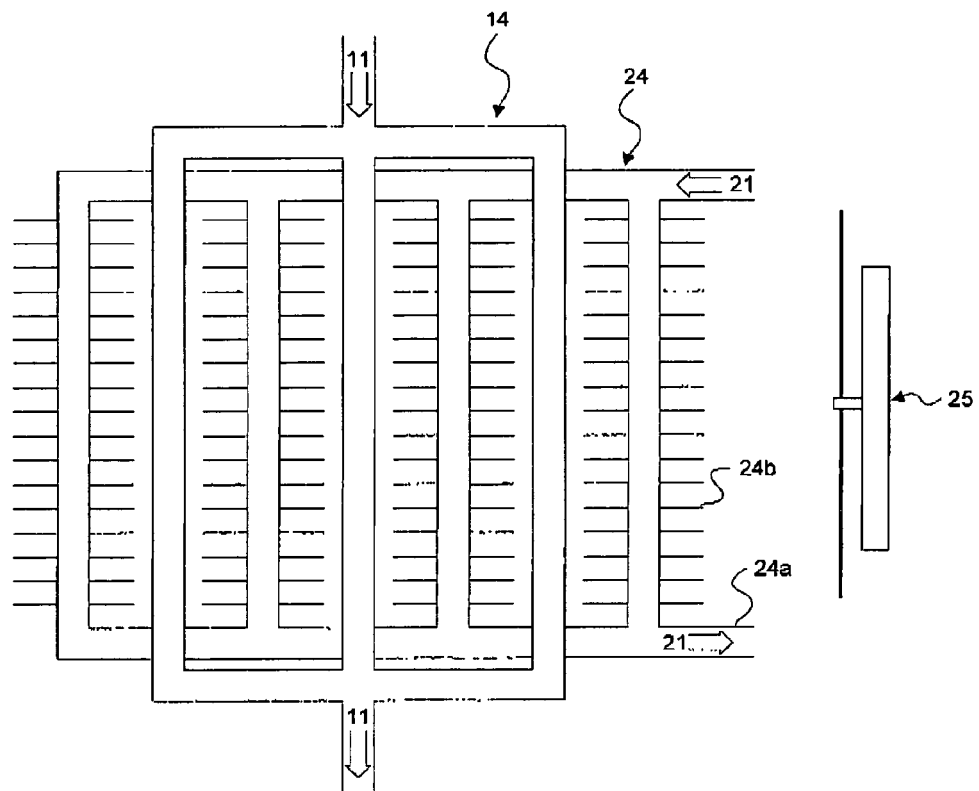


Fig. 7



EUROPEAN SEARCH REPORT

Application Number
EP 11 40 0050

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Place of search The Hague		Date of completion of the search 27 March 2012	Examiner Melo Sousa, Filipe
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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