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(54) **Vapour phase drying apparatus**

(57) The present invention relates to a vapour phase drying apparatus (1), comprising a drying chamber (2) configured to receive an article to be dried by means of the apparatus (1); and a plurality of evaporator cells (3) positioned in the drying chamber (2) and configured for being connected to a source of volatile fluid (20) and a source of heat (15) for evaporation of the volatile fluid; wherein each of the plurality of evaporator cells (3) has an opening (14) such that vapour of the volatile fluid can be released from the cell (3) into the drying chamber (2) through said opening. The invention also relates to such an evaporator cell (3).

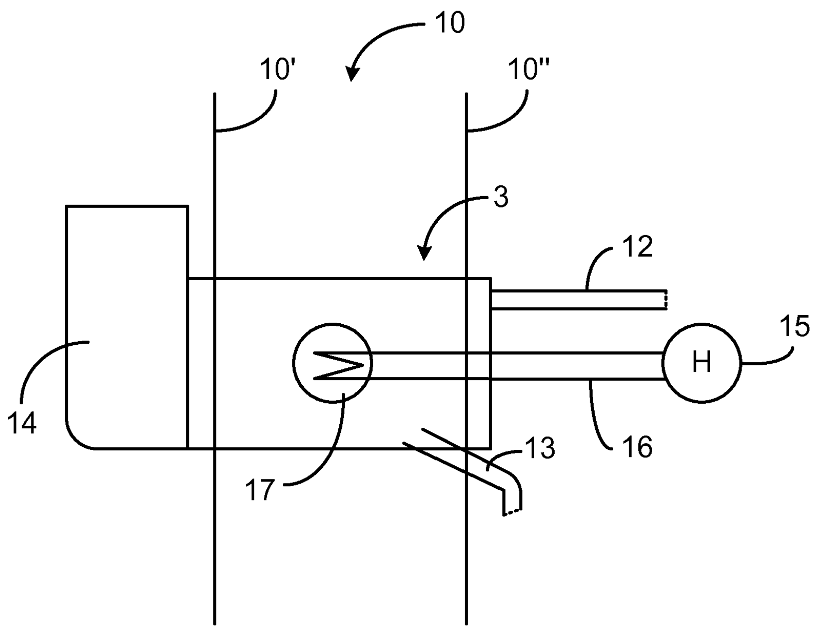

Fig. 2

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Description

TECHNICAL FIELD

[0001] The invention relates to vapour phase drying apparatus, comprising a drying chamber configured to receive an article to be dried by means of the apparatus. The invention also relates to an evaporator cell positioned in the drying chamber of such an apparatus.

BACKGROUND

[0002] Vapour phase drying (VPD) may be used to dry, i.e. remove water moisture, from parts. It may be suitable for drying active parts of super voltage and high-capacity transformers, instrument transformers and such. The transformer to be dried is put into a drying chamber or autoclave, which is then evacuated. Kerosene is evaporated by an evaporator and the gaseous kerosene is contacted with the transformer in the autoclave, where it is condensed on transformer surfaces thereby heating the transformer. Condensed kerosene is collected at the bottom of the autoclave and is returned to a storage and then forwarded to the evaporator for reuse. The kerosene is collected and pumped by a circulation pump to a storage vessel and from there back to the evaporator in a vacuum or low pressure environment since the kerosene collector and evaporator are evacuated together with the autoclave.

[0003] When the transformer has reached the desired temperature, the addition of kerosene vapour to the autoclave is stopped and the pressure is reduced by a vacuum pump to remove water and kerosene vapour. The heating in combination with the reduced pressure dries the transformer. An important point is that the saturation pressure of kerosene is lower than the saturation pressure of water, but higher than the saturation pressure of transformer oil.

[0004] A vapour phase drying apparatus for drying transformers is disclosed in US 4,292,744.

[0005] The evaporator can be placed inside the autoclave as in, for example US 2002/0178604. However, a problem with this is that:

- the evaporator takes up space in the autoclave that could be used for the part that is drying
- the evaporator will be very long to keep up the heating element area
- it is not possible to use cranes inside the autoclave in order to position the often heavy and bulky evaporator, except the unusual top loaded variants
- heating media pipes have to be connected inside the autoclave which may be complicated.

[0006] Alternatively, the evaporator can be placed outside the autoclave as in, for example US 6,732,448. An external evaporator can be bulky and less efficient, less integrated with the autoclave. Further:

- there can be a pressure drop between the external evaporator and the autoclave
- required floor area for the whole vapour phase drying apparatus will be larger than with an integrated evaporator.

[0007] The evaporator of the vapour phase drying apparatus is designed and built for one effect level and is not very flexible on the amount of heat it can deliver and there is a hard upper limit on the maximum effect it can deliver. It is hard to retrofit the existing solutions to increase the effect level.

[0008] Another problem with known evaporators is that it is difficult to remove and discard unwanted transformer oil from the evaporator, without at the same time having to discard the kerosene in the evaporator. As the kerosene is circulated between the autoclave and the evaporator, it is to an increasing degree polluted with oil and/or paraffin, which is not evaporated but rather distilled and enriched in the evaporator, reducing the efficiency of the evaporator. The evaporator thus needs to be regularly emptied of oil and kerosene.

[0009] Known evaporators use a shell and tube heat exchanger. Such heat exchangers are suitable since they have space to accommodate the vapour formed therein without causing blockage or flash boiling which can occur in narrow passages of other heat exchangers. However, such spacious shell and tube heat exchangers have a relatively low efficiency.

SUMMARY

[0010] It is an objective of the present invention to solve at least some of the problems of the prior art.

[0011] According to an aspect of the present invention, there is provided a vapour phase drying apparatus, comprising: a drying chamber configured to receive an article to be dried by means of the apparatus; and a plurality of evaporator cells positioned in the drying chamber and configured for being connected to a source of volatile fluid and a source of heat for evaporation of the volatile fluid; wherein each of the plurality of evaporator cells has an opening such that vapour of the volatile fluid can be released from the cell into the drying chamber through said opening.

[0012] According to another aspect of the present invention, there is provided an evaporator cell configured for being positioned in a drying chamber of a vapour phase drying apparatus, and configured for being connected to a source of volatile fluid and a source of heat for evaporation of the volatile fluid, the cell comprising: a liquid-liquid plate heat exchanger for heat exchange between a liquid of the heat source and the volatile fluid, for evaporation of said volatile fluid; and an opening arranged such that vapour of the volatile fluid can be released from the cell into the drying chamber through said opening.

[0013] By means of the opening of the evaporator (here called an evaporator cell) directly into the drying chamber, vapour formed in the evaporator can exit the evaporator essentially directly when formed and does not have to be pressed through piping etc. which forms a vapour over pressure in the evaporator. By the vapour thus being efficiently removed from the evaporator, a more efficient heat exchange can be achieved. Further, by the reduced amount of vapour in the evaporator, a more efficient heat exchanger than a shell and tube heat exchanger can in some embodiments be used, e.g. a plate heat exchanger, whereby the efficiency of the evaporator is improved. A plate heat exchanger which by means of the opening essentially is open to one upper end, allowing the vapour to leave the evaporator directly from the heat exchanger, may for example be used. The improved efficiency may also allow the heat exchanger, and thus the evaporator, to be made smaller and more compact, reducing the bulkiness of the evaporator in the drying chamber. In some embodiments, a plurality of evaporator cells may be used in a drying chamber. This implies that each of the plurality of evaporator cells can be made smaller than a corresponding single evaporator, reducing the bulkiness in the drying chamber and allowing the evaporator cells to be placed such that they are less in the way when placing a goods to be dried, e.g. a transformer, in the drying chamber. As discussed above, a smaller evaporator and heat exchanger can be more efficient, allowing the evaporator size to be reduced further. A plurality of evaporator cells also makes the vapour phase drying apparatus more flexible and controllable, since, depending on the heating effect desired, one, some or all of the evaporator cells can be used at any time. Also, the evaporator cells can be placed dispersed in the drying chamber to give a more uniform supply of vapour in different parts of the drying chamber. Further, a plurality of evaporator cells allows for redundancy if one of the cells malfunctions or is removed for maintenance. The vapour phase drying apparatus may thus in some embodiments be configured to be operational also when one or more of the plurality of evaporators is not operating.

[0014] Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined otherwise herein. All references to "a/an/the element, apparatus, component, means, step, etc." are to be interpreted openly as referring to at least one instance of the element, apparatus, component, means, step, etc., unless explicitly stated otherwise. The steps of any method disclosed herein do not have to be performed in the exact order disclosed, unless explicitly stated. The use of "first", "second" etc. for different features/components of the present disclosure are only intended to distinguish the features/components from other similar features/components and not to impart any order or hierarchy to the features/components.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Fig 1 is a schematic cross-sectional view of an embodiment of an apparatus of the present invention.

Fig 2 is a schematic view in longitudinal section of an embodiment of an evaporator cell of the present invention.

Fig 3 is a schematic piping diagram of the connection of a plurality of evaporator cells according to an embodiment of the present invention.

Fig 4 is a schematic view in longitudinal section of an embodiment of an evaporator cell of the present invention, mounted within a side wall of a drying chamber.

Fig 5 is a schematic view in longitudinal section of an embodiment of an evaporator cell of the present invention, mounted within a top wall of a drying chamber between two beams.

DETAILED DESCRIPTION

[0016] The invention will now be described more fully hereinafter with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout the description.

[0017] The term "volatile fluid" should be interpreted broadly. Any fluid which may be evaporated and used for heating an article to be dried in vapour phase drying is included by the term. Preferably, the volatile fluid is more volatile than water. Conveniently, the volatile fluid is a petroleum fraction, such as kerosene.

[0018] The term "piping" and the like is herein used broadly and is not limited to a certain material or design. The term encompasses any type of piping, tubing, conduit or the like. Also, the term encompasses not only regular pipes for transporting a fluid from one place to another, but also tanks, valves, couplings, flanges, nozzles etc. as needed.

[0019] The drying chamber may be any chamber able to receive an article to be dried at reduced pressure, such as an autoclave. The drying chamber may have any size, depending on the article it is designed to receive. The drying chamber does not have to be completely air tight, just tight enough to allow a reduction of a pressure therein by means of a vacuum pump, or the like, while the vacuum pump is in use for lowering the pressure in the drying chamber.

[0020] That an evaporator cell is positioned in the drying chamber implies that the cell extends at least partly inside the drying chamber, e.g. within an outer wall of the drying chamber. The evaporator cell may or may not also extend within an inner wall of the drying chamber.

[0021] The article may be any article that may be dried by vapour phase drying. Conveniently, the article may be an electrical article, such as a transformer or reactor.

[0022] The vacuum pump may be any means able to lower the pressure in the drying chamber, such as a regular vacuum pump arranged to pump a gas phase out from the drying chamber through piping/tubing/conduit putting the vacuum pump in fluid connection with the drying chamber. The gas phase may be released to the atmosphere or may be at least partly condensed for recovering and recycling of vapour pumped out from the drying chamber.

[0023] The evaporator/evaporator cell may be any means able to evaporate the volatile fluid. The evaporator is arranged for fluid connection with the drying chamber. Thus, the evaporator, when operating may be connected, via piping/tubing/conduit, to the drying chamber such that a fluid, e.g. the volatile fluid in gas/vapour phase, may pass from the evaporator to the drying chamber and enter the same. The evaporator may be at a reduced pressure, just as the drying chamber.

[0024] The evaporator has an opening (herein also called a fluid connection) into the drying chamber, when the evaporator cell is positioned in the chamber. This implies a direct fluid connection between the evaporator cell and the chamber without any piping or valves there between which can cause a substantial pressure fall. The opening is through a casing wall of the evaporator cell, e.g. a side wall or upper wall to allow the vapour to leave the cell more easily. A nozzle or fluid guide can in some embodiments be attached to or be part of the opening, for directing the vapour flow in a desirable direction into the chamber.

[0025] In some embodiments, the evaporator cell comprises a compartment (also called a volume) at least partly enclosing the heat exchanger, the compartment being partly filled with the volatile fluid. The heat exchanger may thus be fully or partly immersed in the volatile fluid in said compartment, for efficient supply of volatile fluid to the heat exchanger which is less dependent on the supply of volatile fluid from the volatile fluid source in relation to the rate of vaporisation of the volatile fluid.

[0026] In some embodiments, the evaporator cell is substantially tubular and has an outer diameter of less than 500 mm, less than 350 mm, or less than 250 mm and/or of at least 200 mm or at least 350 mm. The cell may e.g. comprise a pipe, e.g. a metallic pipe, in which the heat exchanger is placed, and such a pipe may have an inner diameter of less than 500 mm and at least 200 mm. As discussed above, there are advantages with a relatively small evaporator cell. Also, an essentially tubular cell can be easily handled and can more easily be inserted into the drying chamber from the outside of the drying chamber through a hole in the wall of said drying chamber, e.g. through a hole in an outer wall of said drying chamber.

[0027] In some embodiments, each of the plurality of evaporator cells is mounted to a wall of the drying chamber. Thus, each cell can be fixed to the wall and volatile fluid and/or heating fluid can be supplied to the evaporator cell via piping inside the drying chamber, e.g. within the wall of the drying chamber to which the cell is mounted, or via piping outside of the drying chamber via a hole in said wall. In some embodiments, the wall is an essentially vertical wall, where it may be more convenient to mount them than e.g. in a bottom wall, but still allows the vapour to contact the goods to be dried on its way up through the drying chamber. In a vertical wall, the cells may also be mounted at a convenient height for an operator to handle them, e.g. inserting and removing the cell, and connecting piping thereto. Additionally or alternatively one, some or all of the evaporator cells may be mounted in a top wall of the drying chamber.

[0028] Each of the evaporator cells may e.g. comprise a flange, e.g. a circumferential flange, by which the cell is attachable to the wall. This may be a convenient way of mounting the cell to the wall, especially if the cell extends through a hole in the wall.

[0029] In some embodiments, each of the plurality of evaporator cells at least partly extend through the wall, allowing the cell to be accessible and/or removable from the outside of the drying chamber. By extending through a hole in the wall, the evaporator cell can e.g. be inserted into and/or removed from the chamber from the outside of the chamber e.g. by hand. By means of such a hole in the wall and by means of the relatively small size and weight of the evaporator cell of the present invention, the cell need not be winched in through the main opening of the chamber and then mounted. In some embodiments, the evaporator cell may be fastened to the wall by means of a flange on the outside of the wall.

[0030] In some embodiments, each of the plurality of evaporator cells is mounted between an outer wall and an inner wall of the drying chamber wall such that the cell extends from the outer wall towards but not substantially beyond the inner wall. In this way, the cells may be mounted inside the wall, not taking up much space within the inner wall, allowing that space to be more fully used for the goods to be dried. The size of the drying apparatus can thus be reduced. Also, the evaporator cells may be more protected from impact with the often heavy goods. In some embodiments, a minor part of the evaporator cell extends beyond the inner wall into the chamber, e.g.

less than 50%, less than 30%, less than 20% or less than 10% of the longitudinal length of the evaporator as counted from the outside or inside of the outer wall extends beyond the inside of the inner wall.

[0031] In some embodiments, the source of heat is a liquid source of heat and each of the cells comprises a liquid-liquid heat exchanger for heat exchange between the liquid of the heat source and the volatile fluid, for evaporation of said volatile fluid. As discussed above, a liquid-liquid heat exchanger may be conveniently used, instead of e.g. an electrical heater or a burner for supplying the heat of evaporation in the evaporator cell. Alternatively, the source of heat is steam and the heat exchanger is a liquid-steam heat exchanger.

[0032] In some embodiments, the heat exchanger is a plate heat exchanger. As discussed above, a plate heat exchanger can provide a more efficient heat exchange than e.g. a shell and tube heat exchanger, but is not suitable for regular evaporators where the vapour phase needs to be accommodated. A plate heat exchanger has a high heat exchanging area per volume, whereby the evaporator cell can be made small and highly efficient.

[0033] In some embodiments, the apparatus comprises a first control system configured for individually controlling a flow of heat from the source of heat to each of the evaporator cells. By means of the control system, the heat supplied to each of the evaporator cells can be controlled, whereby the total heating effect of the apparatus can be controlled, as well as the heating effect in different parts of the heating chamber since different evaporator cells may be allotted different amounts of heat. The cells can e.g. be dispersed throughout the chamber and/or the vapour flow from each of the cells can be guided in different directions.

[0034] In some embodiments, the apparatus comprises a second control system configured for individually controlling a flow of volatile fluid from the source of volatile fluid to each of the evaporator cells. The control system may e.g. ensure that the level of volatile fluid in the compartment enclosing the heat exchanger is within a desired range for each evaporator cell. For instance, if more heat is supplied to a cell, more fluid will be evaporated and thus more volatile fluid will need to be supplied to that cell. Also, if a cell is turned off or removed for service, the supply of volatile fluid may conveniently also be turned off.

[0035] The first and second control systems may be part of the same control system, or they may be run independently of each other. Any of the control systems may be under automatic control by means of sensors connected to a central processing unit.

[0036] Figure 1 schematically illustrates an embodiment of the apparatus 1 of the present invention, in cross-section as seen from within the drying chamber 2 towards the wall 10 of said drying chamber. At the lower part of the wall 10, four substantially tubular evaporator cells are mounted to said wall. The evaporator cells are seen along their longitudinal axes, i.e. the end surfaces are seen at 3. The evaporators extend into the drying chamber 2, possibly through the wall 10. As discussed above, the evaporator 3 may in some embodiments extend through a through hole in the wall 10 and be mounted to the wall 10 by means of a circumferential flange attached/fastened to an inside or outside of the wall 10.

[0037] Figure 2 schematically illustrates an embodiment of an evaporator cell 3 of the invention, mounted in a chamber wall 10 of the drying chamber 2. In this embodiment, the chamber wall 10 comprises an inner wall 10' and an outer wall 10" separated by beams. Any space between the inner and outer wall is conveniently at least partly filled with insulation for conserving heat in the drying chamber. However, here the evaporator cell 3 is also mounted between and extending through a through hole of both the inner wall 10' and the outer wall 10" of the chamber wall 10, between the beams. The evaporator cell 3 has been inserted through the through hole from the outside of the chamber, and fastened to the outer wall 10" by means of a flange fixed to the outside surface of said outer wall 10". Additionally or alternatively, the evaporator may be fixed to the inside of the outer wall 10" and/or to the inside or outside of the inner wall 10', by means of a flange or such. The evaporator cell 3 is arranged to be in fluid connection with the drying chamber 2 via an opening 14. The evaporator cell is further arranged for using heat from the source of heat 15 for evaporating a volatile fluid from the source of volatile fluid such that the volatile fluid in vapour form can enter the drying chamber 2 by means of the fluid connection opening 14. In the embodiment of figure 2, the opening 14 comprises a nozzle or guiding means arranged to guide the vapour in a certain direction inside the chamber 2. Said nozzle or guiding means is adapted to invoke a minimal pressure drop to the vapour flow. The opening 14 may be in the form of a guiding pipe having a relatively large diameter so as not to prevent the vapour from leaving the heat exchanger and the cell, e.g. of an inner diameter of at least 100 mm or at least 200 mm, depending on the size of the cell. The evaporator cells are located between the beams in a dead volume normally only used for insulation and/or wall heating distribution. The advantage is that the evaporators require less or no extra space in drying chamber. By using a plurality of evaporator cells, it is possible to install them on all walls, around an article/goods to be dried or any combination of walls. Since the evaporator cells 3 are modular it is possible to design a vapour phase drying apparatus with a scalable heat input by more or less number of cells 3. The modular evaporator cells can also be used to retrofit old vapour phase drying apparatus that need more vapour input where the existing evaporator cannot produce more vapour. A source of volatile fluid is connected via fluid piping 12 to the evaporator cell 3. Volatile fluid can thus be supplied to the cell 3 via the piping 12. There is possibly also a connection/outlet piping 13 to the evaporator cell 3 to draw out un-evaporated volatile fluid from the evaporator cell 3. Transformer oil or other substance polluting the volatile fluid may also be drained via pipe 13. Thus, for instance, the evaporator can be drained from fluid via the outlet 13, e.g. to clean the evaporator. The evaporator cell 3 comprises a compartment/volume at least partly filled with volatile fluid, and arranged in the volume is a heat exchanger 17. A hot fluid from a heat source 15 is circulated through the heat exchanger 17 via the piping 16. The heat exchanger is preferably of plate or plate & shell type, but any other type heat exchanger may work. The evaporator cell 3 can be modular.

[0038] The smaller and more efficient evaporator cells described herein also improves the handling of oil or paraffin pollution of the volatile fluid. An evaporator cell 3 can run until it is almost full of oil (which is not evaporated by the cell) with most or all of the volatile fluid distilled away. Then the oil can be removed via the outlet 13, and new volatile fluid is supplied via the inlet piping 12. Alternatively, the piping 12 can be used also for removing the oil, e.g. if the piping 12 is positioned at a lower or bottom part of the cell 3.

[0039] Figure 3 schematically illustrates an embodiment of how to connect a plurality of evaporator cells 3 of the present invention. The source of volatile fluid 20 is connected to a pump 21 arranged to pump volatile fluid from the source 20 to the evaporator cells 3 via the inlet piping 12 of each of the evaporator cells 3. In the embodiment of figure 3, three series connected evaporator cells 3 are shown, but any suitable number of cells can alternatively be used. Only the leftmost cell 3 is provided with reference numerals, but the other two are corresponding. Any un-evaporated volatile fluid can be fed back via the outlet piping 13 to the source 20. Heating fluid from a heat source 15 can be circulated via piping through the heat exchanger 17 of each cell 3. The evaporator cells 3 are configured to be at least partly filled with solvent by means of the circulation pump 21. A drainage hole can be provided to guarantee that the cells will not be overfilled. In some embodiments, the outlet 13 can function as the drainage hole, e.g. if it is positioned at an upper part of the cell 3. Depending on feed back flow from the cells and/or the level of volatile fluid in the respective cells, the flow of volatile fluid (e.g. kerosene) can bypass the cells and fed back to tank 20 via the valve "F" in figure 3. Thus, the pump 21 may continue to circulate the volatile fluid without overfilling the cells 3. This bypass flow may be controlled by an automatic control system based on input from sensors e.g. detecting the level of fluid in each of the cells 3. Valve(s) on the inlet piping 12 by each of the cells may also be used to control the flow of volatile fluid to each of the cells 3 individually. Such individual valves may also be automatically controlled by the control system based on sensors related to the respective cell 3. Similarly, valve(s) of the piping for transporting the heating fluid from the heat source 15 and through the heat exchanger 17 may be used to control the supply of heat to all the cells 3, together and/or individually. Also these valves may be automatically controlled by a control system, e.g. based on sensors detecting the amount of formed vapour produced by each or all of the evaporator cells which enters the drying chamber 2. In the embodiment of figure 3, each evaporator cell has a maximum effect of 100 kW, but other cells 3 with higher or lower maximum effects can be used as needed, e.g. with an effect, or maximum effect, of between 50 and 150 kW. Also, the total evaporator effect can be controlled by selecting how many cells to use, e.g. how many cells that a drying apparatus 1 is equipped with, or how many of the cells 3 of an apparatus 1 which are used simultaneously.

[0040] A vapour phase drying apparatus 1 with a plurality of modular evaporator cells 3 have a number of advantages, some of which are mentioned below. The standard, single internal or external evaporator for a vapour phase drying apparatus is a bulky piece of equipment, which can be more than 10 meters in length and with all the piping it will occupy a large area and/or volume. The evaporator cells 3 may be placed in an unused space in the drying apparatus and space outside and inside of the apparatus is saved. Thus, larger goods, e.g. transformers, can be dried by means of the apparatus 1 and valuable floor space in the factory is freed.

[0041] Installation of a standard evaporator in the drying chamber 2 is complicated and difficult since it is not possible to use a crane inside the chamber, whereas the installation of the smaller evaporator cells 3 may be relatively simple. The cells 3 are smaller and are placed in an area that is easier to reach e.g. from the outside via a through hole in a vertical or horizontal wall 10 of the chamber 2.

[0042] Another advantage of the multiple evaporator cell 3 installation of the present invention over an installation of a single evaporator in the drying chamber 2, is that no heating media pipes may have to be installed inside the drying chamber 2. Instead, such piping may be installed on the outside of the chamber and connect to each cell 3 where they are mounted to the wall 10 of the chamber 2.

[0043] The apparatus 1 may more easily be designed for any vapour flow e.g. a multiple of the effect of a cell 3. It is easy to get a lower amount of vapour flow by disconnecting a few cells 3 or a higher amount of flow by connecting a few more cells. This modular property of the cells may easily be controlled, individually, for a quick change in total vapour flow.

[0044] Another advantage of the multiple evaporator cell 3 installation of the present invention is that there may be practically no pressure drop between an evaporator cell 3 and the drying chamber 2, e.g. allowing the use of more efficient and less bulky heat exchangers 17 as discussed above.

[0045] The modular cells 3 may be placed around the chamber 2 to optimize the flow of vapour in the chamber, e.g., to avoid cold spots within the chamber 2. Furthermore, the modular cells 3 may easily be added during retrofitting to allow higher amount of vapour flow in an old vapour phase drying apparatus 1, e.g. by providing a through hole through which an evaporator cell 3 can be mounted.

Example 1

[0046] Figure 4 shows an embodiment of an evaporator cell 3, where the cell is similar to that shown in figure 2 and is mounted between an inner wall 10' and an outer wall 10" of a vertical side wall of the drying chamber 2. The cell does not extend beyond the inner wall 10' into the chamber 2. The opening 14 comprises a guiding pipe which directs the vapour into the chamber 2 as illustrated by the arrow in figure 4.

Example 2

[0047] Figure 5 shows an embodiment of an evaporator cell 3, where the cell is similar to that shown in figure 2 and is mounted between an inner wall 10' and an outer wall 10" between two beams 30 of a horizontal top wall of the drying chamber 2. The cell does not extend beyond the inner wall 10' into the chamber 2. The opening 14 comprises a guiding pipe which directs the vapour downward into the chamber 2 as illustrated by the arrow in figure 5.

[0048] Below follow some other aspects and embodiments of the present invention.

[0049] According to an aspect of the present invention, there is provided a vapour phase drying apparatus (1) comprising, a drying chamber (2) configured to receive an article to be dried by means of the apparatus and an evaporator (3) that is connected to a source (20) of volatile fluid and a source (15) of heat and the evaporator is arranged to be in fluid connection with the drying chamber and using heat from the source of heat for evaporating a volatile fluid from the source of volatile fluid such that the volatile fluid in vapour form can enter the drying chamber by means of the fluid connection (14). The vapour phase drying apparatus comprises one, or two or more, evaporator cells that are arranged on the wall of the drying chamber or autoclave.

[0050] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein the evaporator cell (3) comprises a volume and within the volume a heat exchanger (17) is arranged and the volume is partly filled with volatile fluid.

[0051] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein a hot fluid from the source of heat (15) is circulated in the heat exchanger (17).

[0052] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein the volatile fluid in the volume is circulated to and from source of volatile fluid (20).

[0053] According to an aspect of the present invention, there is provided a vapour phase drying apparatus where hot fluid from the source of heat (15) is one of hot oil, hot water, steam, or other heating media.

[0054] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein the evaporator (3) is arranged between an inner wall (10') and an outer wall (10").

[0055] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein a control system is arranged to, possibly individually, control the flow of heat or heat distribution to each evaporator.

[0056] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein a control system is arranged to, possibly individually, control the flow of volatile fluid to and from each evaporator (3).

[0057] According to an aspect of the present invention, there is provided a vapour phase drying apparatus wherein at least part of the piping is integrated in the drying chamber (2) walls (10', 10").

[0058] The invention has mainly been described above with reference to a few embodiments. However, as is readily appreciated by a person skilled in the art, other embodiments than the ones disclosed above are equally possible within the scope of the invention, as defined by the appended patent claims.

Claims

1. A vapour phase drying apparatus (1), comprising:

    a drying chamber (2) configured to receive an article to be dried by means of the apparatus; and
    a plurality of evaporator cells (3) positioned in the drying chamber (2) and configured for being connected to a source of volatile fluid (20) and a source of heat (15) for evaporation of the volatile fluid;
    wherein each of the plurality of evaporator cells has an opening (14) such that vapour of the volatile fluid can be released from the cell into the drying chamber through said opening.

2. The apparatus of claim 1, wherein each of the plurality of evaporator cells is mounted to a wall (10) of the drying chamber.

3. The apparatus of claim 2, wherein the wall is an essentially vertical wall.

4. The apparatus of claim 2 or 3, wherein each of the evaporator cells (3) comprises a flange by which the cell is attachable to the wall (10).

5. The apparatus of any claim 2-4, wherein each of the plurality of evaporator cells at least partly extend through the wall, allowing the cell to be accessible and/or removable from the outside of the drying

chamber.

6. The apparatus of any claim 2-5, wherein each of the plurality of evaporator cells (3) is mounted between an outer wall (10") and an inner wall (10') of the drying chamber wall (10) such that the cell extends from the outer wall towards but not substantially beyond the inner wall.

7. The apparatus of any preceding claim, wherein the source of heat (15) is a liquid source of heat and each of the cells comprises a liquid-liquid heat exchanger (17) for heat exchange between the liquid of the heat source and the volatile fluid, for evaporation of said volatile fluid.

8. The apparatus of claim 7, wherein the heat exchanger is a plate heat exchanger.

9. The apparatus of any preceding claim, further comprising a first control system configured for controlling a heat distribution from the source of heat (15) to the evaporator cells.

10. The apparatus of any preceding claim, further comprising a second control system configured for individually controlling a flow of volatile fluid from the source of volatile fluid (20) to each of the evaporator cells.

11. An evaporator cell (3) configured for being positioned in a drying chamber (2) of a vapour phase drying apparatus (1), and configured for being connected to a source of volatile fluid (20) and a source of heat (15) for evaporation of the volatile fluid, the cell comprising:

a liquid-liquid plate heat exchanger (17) for heat exchange between a liquid of the heat source and the volatile fluid, for evaporation of said volatile fluid; and
an opening (14) arranged such that vapour of the volatile fluid can be released from the cell into the drying chamber through said opening.

12. The cell of claim 11, further comprising a compartment at least partly enclosing the heat exchanger (17), the compartment being at least partly filled with the volatile fluid.

13. The cell of claim 11 or 12, wherein the cell (3) is substantially tubular and has an outer diameter of less than 500 mm.

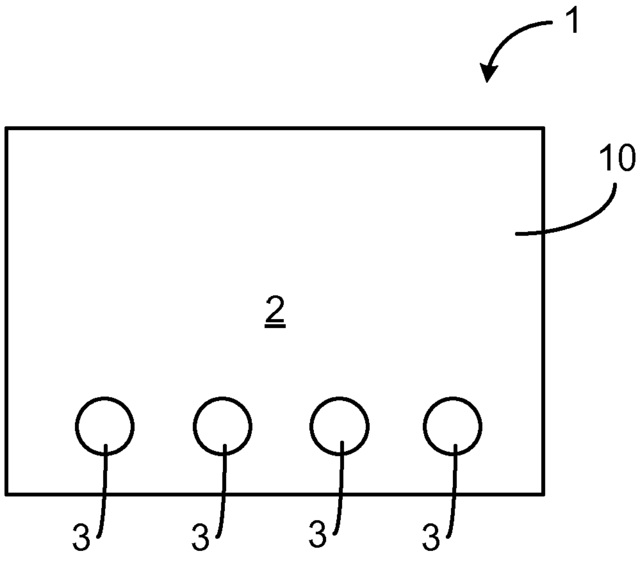

Fig. 1

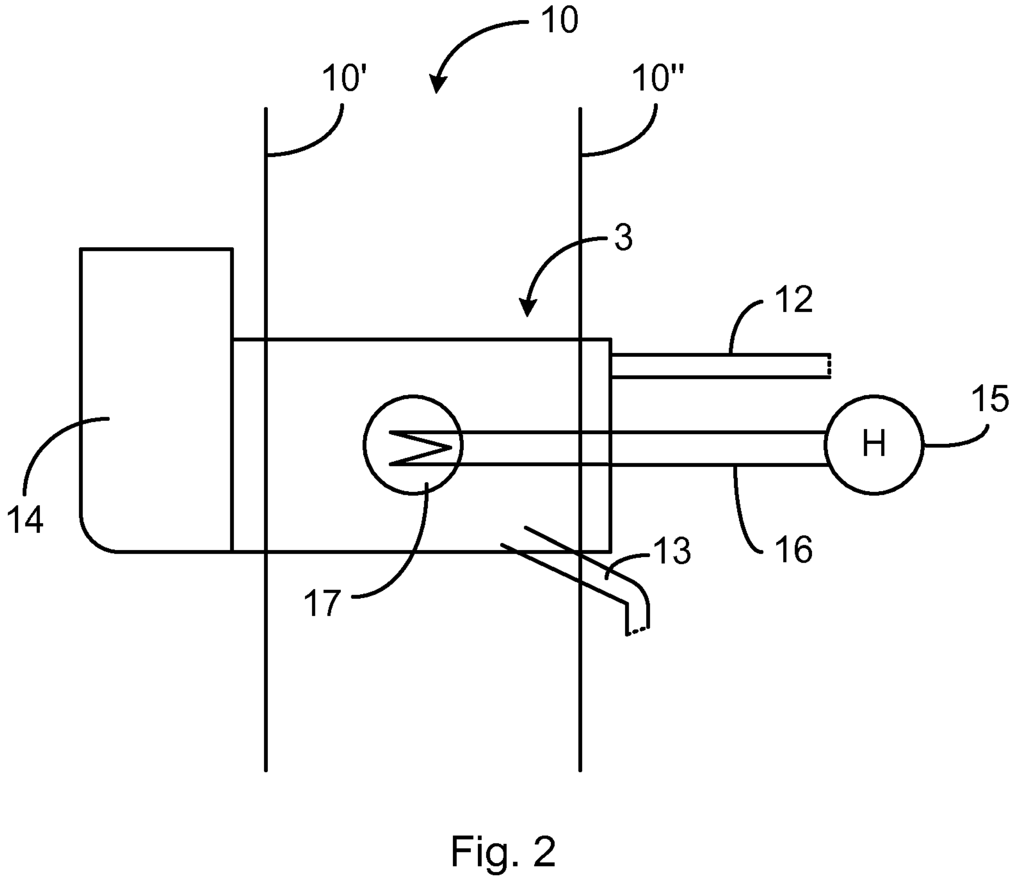

Fig. 2

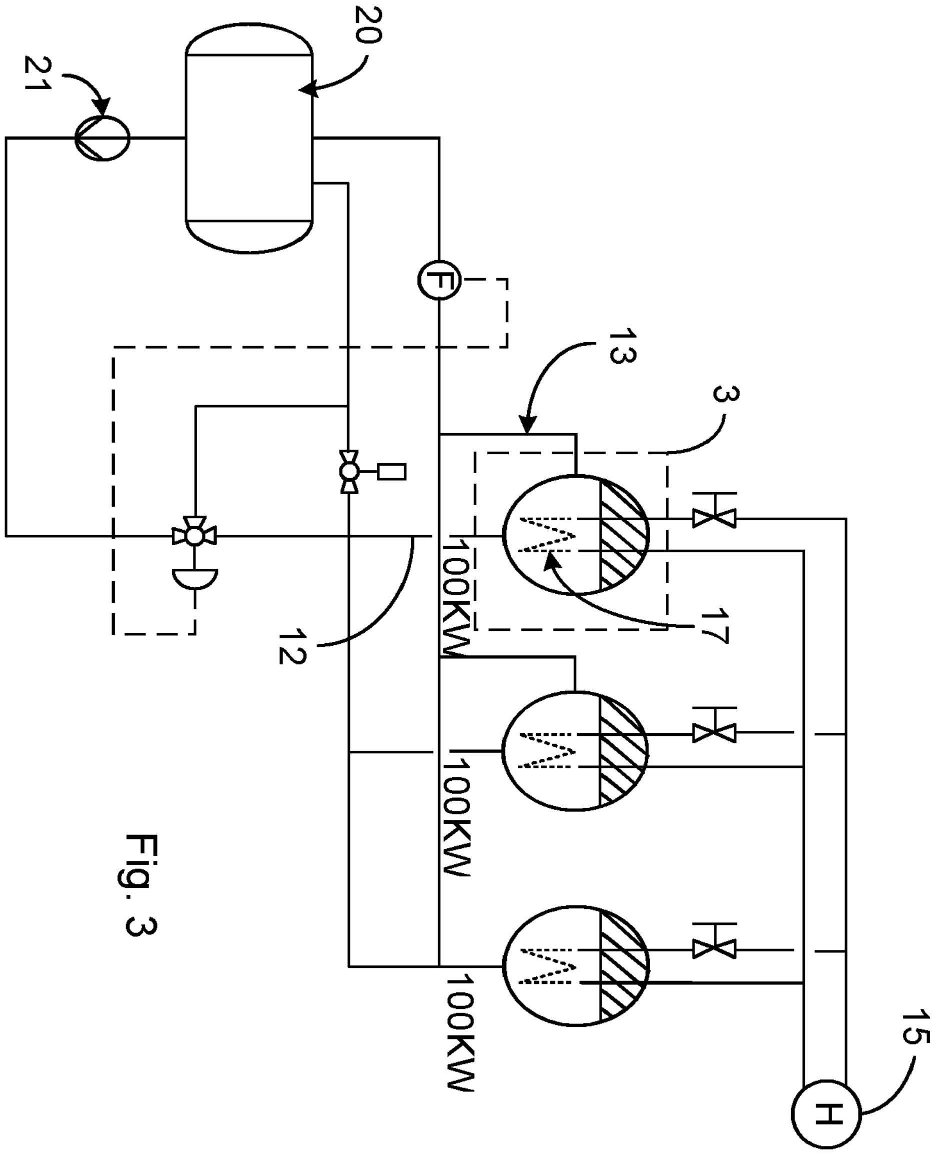

Fig. 3

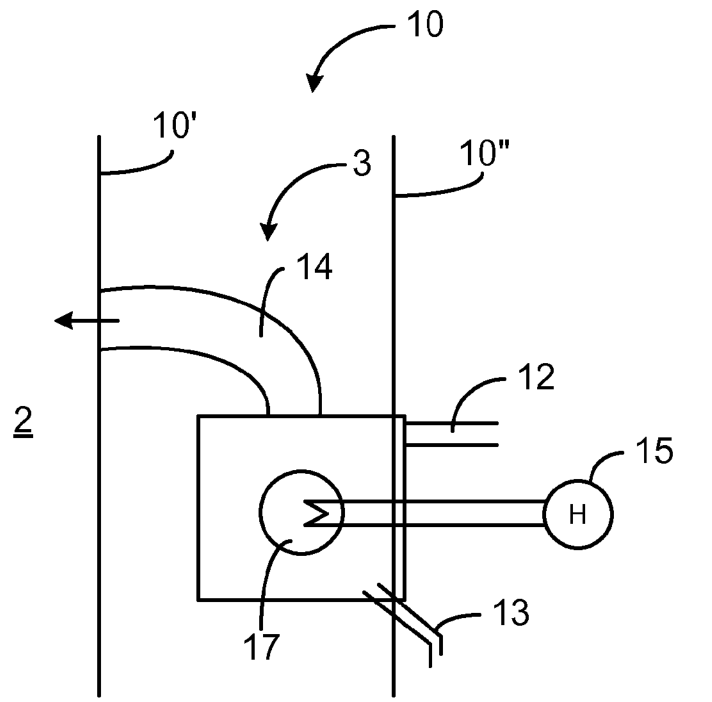

Fig. 4

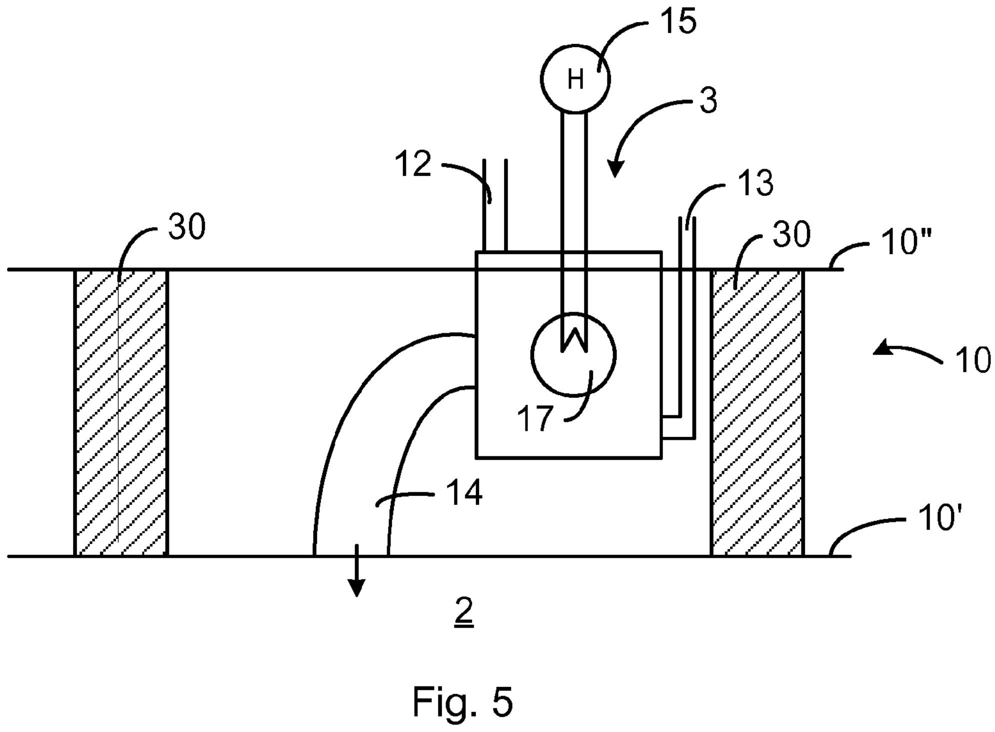

Fig. 5

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EUROPEAN SEARCH REPORT

Application Number
EP 13 15 0440

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Place of search	Date of completion of the search	Examiner
The Hague	19 December 2013	Hauck, Gunther

CATEGORY OF CITED DOCUMENTS

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