(19) DANMARK

(10) **DK/EP 3175196 T3**

(12) Oversættelse af europæisk patentskrift

Patent- og Varemærkestyrelsen

(51) Int.Cl.: ***F 24 H 7/04 (2006.01)*** ***F 28 D 20/00 (2006.01)*** ***F 28 F 1/30 (2006.01)*** ***F 28 F 1/40 (2006.01)***

(45) Oversættelsen bekendtgjort den: **2024-05-13**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2024-02-21**

(86) Europæisk ansøgning nr.: **15747785.2**

(86) Europæisk indleveringsdag: **2015-07-31**

(87) Den europæiske ansøgnings publiceringsdag: **2017-06-07**

(86) International ansøgning nr.: **EP2015067658**

(87) Internationalt publikationsnr.: **WO2016016428**

(30) Prioritet: **2014-07-31 FR 1457433**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

(73) Patenthaver: **Commissariat à l'Énergie Atomique et aux Énergies Alternatives, 25, Rue Leblanc , Bâtiment "Le Ponant D", 75015 Paris, Frankrig**

(72) Opfinder: **MARTINELLI, Matthieu, 30 rue André Rivoire, 38100 Grenoble, Frankrig**
CHAZELLE, Benjamin, 4 rue Charles Baudelaire, 38400 Saint-Martin d'Hères, Frankrig
COUTURIER, Raphaël, 12 rue Jean Moulin, 38360 SASSENAGE, Frankrig

(74) Fuldmægtig i Danmark: **Plougmann Vingtoft A/S, Strandvejen 70, 2900 Hellerup, Danmark**

(54) Benævnelse: **APPARAT TIL LAGRING AF ENERGI VED HJÆLP AF ET FASEOMDANNELSESMATERIALE SAMT DERTIL HØRENDE FREMGANGSMÅDE TIL LAGRING**

(56) Fremdragne publikationer:
WO-A1-98/34073
AT-A1- 508 992
DE-A1-102009 057 904
DE-U1-202008 017 601
JP-A- 2007 032 866
US-A- 5 687 706

Description

TECHNICAL FIELD

The present invention relates to an energy storage device with phase change material and an associated storage method.

The field of the invention relates to Thermal Storage Systems (TSS) with Phase Change Materials (PCM); and more specifically, the integration of a system making it possible to optimise the availability of stored thermal energy.

The invention will have its application in urban or rural electrical and heat networks. The invention can also find applications in the development of electrical and thermal “smart grid” networks, as well as in the interactions between these networks.

PRIOR ART

The heat networks are constituted of at least one heat source (thermal power stations, thermal solar panels, geothermal source, etc.), a fluid network enabling the transport of calories to users by way of a heat-transfer fluid and optionally a return network. To each subscriber, a heat exchanger corresponds, enabling the thermal transfer from the primary circuit (network connected to the heat source) to a secondary circuit; this second circuit is the property of the subscriber, and is crossed by hot water (<100°C). This exchanger is the delivery point of the thermal energy, which is called the exchanger assembly, meter, and the different sets of valves: a substation.

The charge of a heat network fluctuates a lot, on average over the year, the production units operate at 25% of their capacity, the consumption peaks are 4 times greater than the average charge. These peaks (morning, evening) represent around 30% of the thermal consumption of a typical day of heating. Additional (and emergency) generators are generally heavy fuel oil, natural gas or carbon thermal power stations, which are polluting and not always inexpensive. Using a thermal storage system which would store calories while demand is low and would reinject them over the network during consumption peaks could overcome this problem.

The thermal storage can be achieved by state change enthalpic storage. In this case, storage is done via the phase change of a material. It is phase change enthalpy, most often during the solid/liquid state change, which is stored. This energy, which is absorbed during melting and released during solidification, results from the establishment, or from the rupture, of interatomic or intermolecular bonds. The charge of the storage system is accompanied by the melting of the storage material, while the discharge is performed by the solidification of said material. The material must be wisely chosen according to the target temperature of the storage system, such that its melting point is in the temperature range of use.

The quantity of thermal energy stored during the phase change is expressed with the following relationship:

$\Delta Q = m \cdot h$

m Mass [kg]

h Phase change mass enthalpy [kJ/kg]

One of the major advantages of this technology, is that the phase change is done at constant pressure and temperature. Consequently, the discharge of the stored energy can be done at constant temperature.

The phase change enthalpy is relatively important, compared with the sensitive energy variation of a material. For example, the energy stored in the melting of an ice block (passage from 0 to 1°C) is equivalent to the energy stored in this same quantity of water, if it is heated from 80°C.

Consequently, the storage systems with PCM are interesting, as the quantity of energy stored per volume unit is greater than that obtained by a sensitive system (better storage density) as the range of operating temperatures remains moderate. Due to this, the storage and material volumes are reduced, which decreases the price of the tank, and limits the thermal losses which are proportional to the outer surface of the tank.

The thermal storage has been recently developed around thermodynamic solar power stations, in order to overcome the intermittency of the solar resource. Today, the topic of thermal storage also relates to habitat and heat networks.

In particular, PCM macroencapsulation, tube and calender exchanger and direct contact storage technologies are known.

PCM macroencapsulation consists of placing sealed modules comprising a PCM in a tank. These modules are immersed in a heat-transfer fluid which flows along the modules. The heat-transfer fluid and the PCM will exchange heat. The heat-transfer fluid will transfer it to the PCM during charging, which will lead to melting the latter. The PCM will transfer heat to the heat-transfer fluid during the discharge, which will lead to the solidification of this first one.

Tube and calender exchanger technology is well-known: a calender wherein a fluid circulates is crossed by a bundle of tubes, wherein another fluid flows. The two fluids exchange energy by conduction through the thickness of the tubes. In the case of thermal storage, this technology is adapted, there is no longer an exchange between two moving fluids, but between a heat-transfer fluid which circulates in the tubes and the PCM, which is fixed in the calender (apart from the liquid phase natural convection movements). During charging, the heat-transfer fluid arrives at a temperature greater than the melting point of the PCM and transfers energy to it, which leads to it melting; during the discharge, the heat-transfer fluid enters at a temperature less than the melting point of the PCM and recovers the energy previously stored, which leads to the solidification of the PCM.

The phase change thermal storage of a material is called “direct contact”, if the PCM is in direct contact with the heat-transfer fluid.

As an example, during charging, the hot oil arrives by a supply tube and transfers energy to the PCM, leading to it melting. Having a density lower than the PCM, the oil rises in the top part of the tank, where it is pumped to return into the exchanger where it is reheated. During the discharge, the cold oil arrives by the supply tube, it rises in temperature by exchanging energy with the PCM which is solidified, then rises in the top part of the tank where it is pumped again; in the exchanger, the oil transfer heat to a secondary fluid.

However, despite the thermal energy storage, it is also sometimes difficult to ensure a supply of thermal energy which is satisfactory in terms of quality and quantity during demand peaks.

Document US 5 687 706 A describes an energy storage device, wherein an electrical heat source is used to transfer heat to the PCM disposed in a chamber. A heat transfer circuit is used to transport the energy stored to the outside of the device.

Document DE 20 2008 017061 U1 provides an energy storage device with PCM according to the preamble of claim 1.

There is therefore a need to propose a device enabling a better availability of thermal energy, as well as a better use of current storage devices.

SUMMARY OF THE INVENTION

The present invention proposes, to this end, an energy storage device with phase change material comprising a chamber and a phase change material intended to be contained in said chamber and a thermal heat source comprising a heat-transfer fluid passing through said chamber to provide and extract heat to said PCM, and an electrical heat source configured to only provide heat in said PCM. The electrical heat source makes it possible to generate the heat transmitted to the PCM which stores thermal energy of electrical origin. At the same time, the storage of thermal energy is done by the heat-transfer fluid which transmit it to the PCM. Advantageously, the recovery of the thermal energy equally coming from the electrical energy or from the thermal energy is performed by the heat-transfer fluid in the form of heat.

The invention makes it possible to use two energy sources to store thermal energy. The integration of the electrical heat source to a phase change material storage system, in addition to the usual thermal heat source, optimises the operation of the device by ensuring a better availability of heat in particular during consumption peaks. The invention proposed also makes it possible to enhance, in thermal force, the cess electrical energy produced by a wind farm or a photovoltaic solar farm, for example. It is particularly adapted to local networks, which seek energy independence and where the interactions between heat and electrical networks are at the core of developing renewable energies (REn).

The invention advantageously contributes to providing thermal energy, even in the case of maintenance or breakdown of the thermal heat source thanks to the electrical heat source.

Preferably, the thermal heat source and the electrical heat source are distant from one another. This distance between the two heat sources makes it possible to limit the interferences between the latter enabling an operation of the optimal device with an electrical charge and a thermal charge at the same time. This distance is defined and maintained, for example, by distancing means.

According to the invention, the device comprises an advantageously longitudinal profile, in contact with the phase change material comprising a housing receiving the electrical heat source.

Preferably, the electrical heat source is a thermal resistance. According to an option, the housing comprises a thermal contact agent, wherein the thermal heat source is immersed. This agent enables the thermal continuity between the electrical heat source and the profile.

According to the invention, the device comprises an exchanger immersing in the PCM comprising a tube and wherein the heat-transfer fluid circulates.

Advantageously, the longitudinal profile is in contact with said exchanger.

Advantageously, the exchanger comprises a metal insert surrounding said exchanger tube configured to ensure a thermal conduction with the PCM.

The longitudinal profile is advantageously in contact with said insert. The device according to the invention advantageously makes it possible, in particular by this arrangement, to perform a thermal energy and electrical energy storage simultaneously without damaging interference, said insert in particular playing the role of distancing means.

According to another aim, the present invention relates to an energy storage method comprising a thermal energy storage phase, an electrical energy storage phase and a destocking phase. The method advantageously enables a heat storage from thermal energy and from electrical energy simultaneously without damaging interference, as well as a heat storage from electrical energy simultaneously without interference with a thermal energy destocking.

BRIEF DESCRIPTION OF THE FIGURES

The aims, objectives, as well as the features and advantages of the invention will best emerge from the detailed description of an embodiment of the latter, which is illustrated by the accompanying figures, wherein:

Figure 1: top view of an example of a network formed by exchangers comprising inserts and finned tubes and profiles.

Figure 2: circular finned tubes.

Figure 3: top view of an exchanger, the finned tube of which is placed in an insert.

Figure 4: top view of a profile.

Figure 5: top view of details of fixing means between the inserts and a profile.

Figure 6: profile according to a first embodiment.

Figure 7: profile according to a second embodiment.

Figure 8: top view of an example of a network formed by exchangers comprising inserts and finned tubes and profiles.

Figure 9: profile according to the embodiment illustrated in figure 8.

Figure 10: exchanger according to the embodiment illustrated in figure 8 with an octagonal insert with finned tube.

The accompanying drawings are given as examples and are not limiting of the invention. They constitute principle schematic representations intended to facilitate the understanding of the invention and are not necessarily to the scale of practical applications.

DETAILED DESCRIPTION OF THE INVENTION

Before starting a detailed review of embodiments of the invention, optional features are stated below, which can optionally be used in association or alternatively.

First, it is reminded that the invention is based on a phase change material (PCM) energy storage device, such as defined in claim 1, comprising a chamber intended to receive a phase change material and a thermal heat source comprising a heat-transfer fluid passing through said chamber and configured to provide and extract heat to said PCM, the device comprising an electrical heat source arranged in the chamber configured to only store heat in said PCM.

The device comprises a profile arranged in thermal contact with the PCM and comprising a housing, wherein the electrical heat source is disposed.

Advantageously, the housing of said profile comprises a thermal contact agent ensuring the thermal conductivity between the electrical heat source and said profile.

Advantageously, the electrical heat source is an electrical resistance.

According to the invention, the thermal heat source comprises an exchanger immersing in the PCM and wherein the heat-transfer fluid circulates.

Advantageously, the exchanger comprises a tube comprising peripheral fins shaped to ensure the thermal transfers between the PCM and the heat-transfer fluid contained in said tube.

Advantageously, the exchanger comprises a metal insert surrounding said tube and configured to ensure a thermal continuity with said tube.

According to the invention, the profile is in contact with the exchanger receiving the heat-transfer fluid.

Advantageously, the profile comprises branchings extending from the housing in the direction of the exchanger.

Advantageously, the device comprises a plurality of exchangers and a plurality of profiles arranged at the contacts of at least two exchangers.

According to the invention, the device comprises fixing means between at least one exchanger and one profile.

Advantageously, the exchanger and the profile form a one-piece assembly immersing in the PCM intended to be contained in the chamber.

Advantageously, the thermal heat source and the electrical heat source are arranged at a distance from one another to ensure a thermal independence.

Advantageously, the thermal heat source and the electrical heat source are distant by at least three times the diameter of the tube.

Advantageously, the PCM is a liquid/solid PCM.

According to another aspect, the invention relates to a method for storing thermal energy with at least one phase change material such as defined in claim 12, comprising:

a- an electrical energy storage phase, wherein the electrical heat source transmits heat to the PCM which stores the electrical energy in the form of thermal energy,

b- a thermal energy storage phase, wherein the heat-transfer fluid of the thermal heat source transmits said heat to said PCM which stores the thermal energy,

c- a thermal energy destocking phase, wherein the heat-transfer fluid cools the PCM which releases thermal energy which is recovered by the heat-transfer fluid.

Advantageously, phases a- and b- are performed simultaneously or alternatively.

Advantageously, phases a- and c- are performed simultaneously.

The device according to the invention is an energy storage device with phase change material (PCM). The device makes it possible to store thermal energy, both of thermal origin and of electrical origin.

The invention makes it possible to have two means of charging the storage system: an electrical source and a thermal source. The electrical charge means the charging of the thermal energy storage device from an electrical source and the thermal charge means the charging of the thermal energy storage device from a thermal source. The thermal source can have several origins which can be fuelwood, geothermal, household waste combustion, natural gas, etc., it is also the case for the electrical source which can be of photovoltaic, wind origin, etc.

The device comprises a storage chamber 13 intended to contain at least one PCM 6 and one heat-transfer fluid 4 passing through said chamber 13.

The chamber 13 is conventionally cylindrically-shaped, the walls of which are formed of metal material resistant to the pressure and temperature variations. As an example, the chamber 13 is made of carbon structural steel. The conventional nuances for a pressurised chamber 13 are P235GH, P265GH, P355GH. In the absence of pressure, stainless steels 304, 316 can be used.

According to the type of thermal energy storage device, different configurations are possible.

According to a first embodiment using the encapsulation of the PCM 6, the device comprises a chamber 13 wherein the PCM 6 is placed in encapsulated form in sealed modules immersed in the heat-transfer fluid 4 flowing along the modules and passing through the chamber 13 from an inlet to an outlet.

According to a second embodiment using the direct contact, the PCM 6 and the heat-transfer fluid 4 directly contained in the chamber 13, the heat-transfer fluid 4 passing through the chamber 13 from an inlet to an outlet.

According to a third preferred embodiment using a tube/calender-type exchanger, the PCM 6 is placed directly in the chamber 13 and an exchanger 5 immerses in said PCM 6. The exchanger 5 is a heat-transfer fluid 4 thermal exchanger 5. The exchanger 5 comprises a tube 1, advantageously finned 2, and advantageously an insert 3 which will be described below. The exchanger 5 comprises an inlet and an outlet of the heat-transfer fluid 4 in the chamber 13. The inlet and the outlet are arranged outside of the chamber 13. The inlet and the outlet can be, according to the embodiments, disposed at two opposite ends of the chamber 13, for example, the inlet at the top and the outlet at the bottom, or arranged on one same side, for example, at the top. Preferably, the exchanger 5 is at least partially positioned in the chamber 13.

The heat-transfer fluid 4 is conventionally water, but any other fluid having heat-transfer properties can be used.

Preferably, the device comprises a plurality of exchangers 5 arranged in the chamber 13. Examples of arrangement are illustrated in figures 1 and 8.

The exchanger 5 can be of different types. Preferably, the exchanger 5 comprises a tube 1, advantageously comprising fins 2 such as illustrated in figures 2 and 3. The tube 1 and the fins 2 are made of thermally conductive material such as made of metal, for example, made of steel for the tube 1 and made of aluminium for the fins 2. The tube 1 can be of various sections, as an example, circular such as illustrated in the figures. This type of exchanger 5 has the advantage of ensuring the thermal transfers between the PCM 6 and the heat-transfer fluid 4. The fins 2 can be longitudinal disposed along the tubes, for example. The fins 2 can also be orthogonal, they are thus disposed helically around the tube 1, and can be solidly circular, or segmented.

According to other options, the exchanger 5 can be in the form of a coil which has the advantage of being less expensive or of having plates. Advantageously, the exchanger 5 comprises an insert 3 arranged around the tube 1 and optionally fins 2, if this is provided with them. The insert 3 is a metal element also making it possible to improve the thermal transfers between the PCM 6 and the heat-transfer fluid 4. The insert 3 can relate to a metal matrix connecting several tubes 1 to one another. Advantageously, the insert 3, and the inserts 3, if the device advantageously comprises several exchangers 5 in the chamber 13, make it possible to maintain the tube 1 network. In addition, they improve the thermal conduction within the PCM 6 by playing the role of large fins 2.

The inserts can take several forms, but mainly these are metal profiles having large contact surfaces with the tube 1 or its fins 2 and large contact surfaces with the PCM 6. The insert 3, for example, has a circular section, figures 1 and 3, or octagonal, figure 8 and 10. The insert 3 comprises, according to an option, solid external walls 12 improving the thermal conductivity. Preferably, the inserts 3 are in contact with one another, such as illustrated in figures 1 and 8.

For information and as an illustration, the inserts 3 have an outer diameter of 212mm; the fins 2 have an outer diameter of 57.4mm; the tubes 1 have an outer diameter of 25.4mm and a thickness of 2.7mm.

The storage device can comprise, according to an option, a device for regulating the temperature of the heat-transfer fluid 4. The regulation device makes it possible to control the temperature of the heat-transfer fluid 4 during the use of the energy storage device to provide and extract heat from the PCM 6 contained in the chamber 13.

According to a preferred embodiment, the chamber 13 comprises conventionally metal inner walls. The walls are preferably covered with a coating material intended to avoid contact between the at least one PCM 6 and metal parts. As an example, the coating material is a polymer or a resin, preferably a material of the fluorinated type, such as PTFE, FEP or PFA. This arrangement improves the storage capacities of the PCM 6 by limiting the oxidation of the PCM 6 during storage cycles in contact with oxygen and/or with metal. Advantageously, this arrangement can also be useful to avoid the corrosion of the chamber 13 by the PCM 6, if this is corrosive.

The chamber 13 contains at least one PCM 6. It can be used for mixtures of PCM 6. Below in the description, the reference to a PCM 6 is not limiting. Different PCMs 6 can be used, in particular, for solid/solid transition PCMs 6 or preferably solid/liquid transition PCMs 6. The invention is adapted to a vast variety of PCM 6 and therefore with a large storage temperature range. The two main PCM 6 categories being able to be used are organic (paraffin, fatty acid, alcohol, etc.) and inorganic (salt hydrates, metal alloys, etc.). As a non-limiting example, the PCM 6 is erythritol.

The chamber 13 contains the PCM 6 which surrounds the exchanger 5. The exchanger 5 is buried in the PCM 6 thus ensuring the contact between the PCM and the exchanger. In this way, the exchanger 5 at best recovers the heat variations of the PCM 6.

The PCM 6 is a preferably solid or liquid two-phase material, the passage of which between these two phases stores or releases energy. Preferably, the passage from a first phase to a second phase will require heat which is stored in the PCM 6 in its second phase. On the contrary, the passage from the second phase to the first phase is exothermal and releases the stored heat.

When the energy storage device operates to store thermal energy, the exchanger 5 provides heat in the chamber 13, there is an exchange of heat from the heat-transfer fluid 4 to the PCM 6 through the exchanger 5. This heat will enable the transformation of the PCM 6 from the first phase to the second phase, which will thus store the heat coming from the heat-transfer fluid 4. When the device operates to return the thermal energy, the exchanger 5 cools the PCM 6, there is an exchange of heat from the PCM 6 to the heat-transfer fluid 4 through the exchanger 5, which enables the passage from the second phase to the first phase. This transformation is exothermal. The heat released is recovered by the heat-transfer fluid 4.

The device according to the invention characteristically comprises means for storing the electrical energy in thermal energy by PCM 6.

The device comprises, according to the invention, an electrical heat source. This electrical heat source is placed in the chamber 13, advantageously immersing in the PCM 6. Preferably, said storage means comprise a preferably longitudinal profile 7 in contact with the PCM 6 and comprising a housing 8, wherein the electrical heat source is housed.

The profile 7 comprises a housing 8 advantageously extending longitudinally from one end to the other of said profile 7. The housing 8 is preferably centred in said profile 7. The housing 8 can have various sections, as an example circular, such as illustrated in the figures.

By a contact, this means a thermal contact, i.e. either a direct contact or an indirect contact by at least one conductive element.

It is preferred that the electrical heat source and the housing 8 is of adjusted complementary shape, such as a finger in a glove, to ensure a satisfactory thermal continuity. Failing that, it is possible that the housing 8 of the profile 7 contains a thermal contact agent, wherein the electrical resistance 10 immerses. The thermal contact agent is preferably a fluid. As an example, the thermal contact agent is a thermal oil of the polychlorobiphenyl or polyol type, a metal powder, a molten metal, a PCM identical to or different from that contained in the chamber 13. The thermal contact agent aims to ensure the thermal transfer between the electrical resistance 10 and the profile 7. The electrical heat source is a means for transforming the electrical energy into thermal energy. Preferably, the means for transforming the electrical energy into thermal energy is an electrical resistance. The electrical resistance 10 is also called immersion heater. It can be considered to use a means for transforming the electrical energy into other thermal energy not based on the Joule effect such as the electrical resistance, for example, based on the Peltier effect or also by induction. However, the expected performance is reduced and the device is more expensive and larger. Below in the description, the term “electrical resistance” 10 is used without being limiting to this preferred embodiment.

The profile 7 is preferably a metal profile, for example, made of aluminium. Aluminium profiles have the advantage of being able to be designed industrially, at a relatively low cost, by extrusion. In addition, aluminium is an excellent thermal conductor (200W/m/K).

The profile 7 is, according to the invention in contact with the PCM 6. By contact, this means that the profile is in thermal continuity with the PCM 6.

In the case of encapsulation of the PCM 6 in sealed modules, the profile 7 will be in contact with the PCM 6 contained in the sealed modules. Preferably, the profile 7 is disposed most at the centre of the sealed module, so as to be away from the thermal contact zones between the PCM 6 and the heat-transfer fluid 4. This arrangement enables an electrical charge at the centre of the sealed module containing the PCM 6 and a thermal charge by the walls of the module. These contact zones being disposed at the walls of the sealed modules.

In the case of a direct contact between the PCM 6 and the heat-transfer fluid 4, the profile 7 is immersed in the chamber 13 directly in the PCM 6 and the heat-transfer fluid 4, the thermal contact being immediate. Preferably, the heat-transfer fluid 4 is introduced into the bottom part of the chamber 13, it rises due to its lower density with respect to the PCM 6. The thermal charge of the PCM 6 is done, in this case, through the bottom of the chamber 13. Advantageously, the profile 7 is arranged in the top part of the chamber 13 so as to maintain the thermal charge and the electrical charge at distance. Preferably, the profile 7 contains a vertical part which will enable the creation of a liquid path through the solid PCM 6 and which will facilitate the rising of the heat-transfer fluid 4 and of the liquid PCM 6.

The profile 7 is arranged in thermal contact with the PCM 6 and in contact with the exchanger 5 receiving the heat-transfer fluid 4.

In the preferred case of the invention illustrated in the figures, the profile 7 is immersed in the PCM 6.

Preferably, the profile 7 is configured to enable the thermal continuity between the exchangers 5, more specifically the inserts 3. Preferably, the profile 7 is in contact with these, in order to optimise the thermal transfers on either side to maintain said exchangers 5. The profile 7, with preferably the inserts 3 also, must act as a structure for supporting the finned 2 tubes 1. It is possible to have a profile 7 which would not be in contact with the inserts 3, on the condition that a general structure maintains the exchangers 5, or if the profile 7 is fixed at the top and at the bottom of the chamber 13. To maintain relatively satisfactory thermal transfers, fixing means advantageously maintain the tubes 1/inserts 3/profiles 7 network, or the profile 7 is welded to the chamber 13, advantageously in the lower and/or upper part of the chamber 13, preferably there is no fixing on the side faces of the chamber 13.

According to a preferred embodiment, the ends of the profiles 7, more specifically of the housings 8, are closed, for example, with a stopper welded into the bottom and via the flange of the electrical resistance 10 which is screwed into the top part of the profile 7. The stopper at the bottom and the flange at the top aim to prevent the PCM 6 being placed between the electrical resistance 10 and the profile 7, which could damage the PCM 6 during the heating of the electrical resistance 10 or damage the electrical resistance 10 during the state change of the PCM 6, in particular due to the volume expansion. The welding of a stopper into the bottom is the solution to be favoured, as the sealing is almost guaranteed; for the flange at the top, it enables the invention to be modulable: it is possible to remove or put back electrical resistances, even replace them in case of defect.

The profiles 7 used around the electrical resistances 10 make it possible to improve the actual thermal conductivity of the storage system and this, even if the electrical resistances do not operate; indeed, they play the role of fins. Moreover, the profiles 7 protect the electrical resistance 10 from a possible corrosion, due to the contact with the PCM 6 and facilitates the maintenance of said electrical resistances.

The profile 7 according to the invention is adapted to the exchangers 5, and in particular to the current inserts 3 and tubes 1.

Two examples of embodiments are described below.

The profile 7 illustrated in figure 6 is a profile comprising a central housing 8 within which the electrical resistance 10 is placed. In this case, it can be advantageous to add a thermal contact agent in the housing 8 to ensure a satisfactory thermal conduction between the electrical resistance 10 and the profile 7. Branchings 9 extending from the housing 8. This branchings 9 can take several forms, that illustrated corresponding to three branchings 9 extending from the housing 8 centrifugally. The branchings 9 are shaped to create contact surfaces with the PCM 6 and the exchangers 5. These branchings 9 have, for example a T-shape. The external flat part of the T is advantageously intended to be in contact with the exchanger 5, more specifically with the insert 3. The profile 7 is arranged in the gaps between the exchangers 5. The profile 7 is advantageously in contact with several inserts 3. This profile 7 has the advantage of being light and small for the device leaving space for the PCM 6.

The profile 7 illustrated in figure 7 is a solid profile comprising a central housing 8 within which the electrical resistance 10 is arranged. The profile 7 has a triangular section, the peaks of which are flattened, so as to form contact surfaces with the exchangers 5 more specifically with the inserts 3. This profile 7 is more resistant, it is to be favoured if the chamber 13 is large and that a great solidity is required.

According to the invention, the device comprises fixing means 11 between the profile 7 and the exchanger 5, more specifically the insert 3. An example of fixing means 11 is illustrated in figure 5. Notches are formed on the external surface of the inserts 3, wherein the flat part of the T of the profile 7 is positioned, for example, by sliding.

Preferably, the exchangers 5 and at least one profile 7 are one-piece. There is a mechanical solidarity between the exchangers 5 and said at least one profile 7 ensuring their maintenance in the chamber 13, advantageously without other fixing.

As an example, in views of the lengths and powers which could be considered for this type of device, the nominal diameters of the immersion heaters 5 would be around 5 to 10cm. The profiles 7 and the inserts 3 must consequently be designed, such as illustrated in figures 8 to 10.

There are infinite geometries, in order to adapt the insert 3 and profile 7 network according to the tubes 1, to the fins 2 and to the electrical resistances. It must be retained that the shapes of the inserts 3 and of the profiles 7 must be achieved, such that the fixing of the assembly forms a structure making it possible to support the tube 1 network; it is also necessary that the geometries optimise the energy transfers between the electrical resistance 10 and the PCM 6, by the profile; likewise, it is absolutely preferable to increase the exchange surface between the profiles 7 and the inserts 3.

According to an advantageous feature of the invention, the electrical resistance 10 is placed in a profile 7, itself immersed in the PCM 6 and delocalised with respect to the thermal charge. The electrical heat source is delocalised from the thermal heat source. The thermal heat source is distant from the electrical heat source. By “delocalised”, this means that the electrical resistance 10 and the thermal charge achieved by the heat-transfer fluid 4 are away from one another, so as to not interfere. The distance is such that there is a thermal independence between the two heat-transfer fluids 4 and 10. Indeed, if the electrical resistances were located along the finned 2 tubes 1, resistance wound around the tube, for example, then the electrical charge would considerably affect the thermal charge: the electrical charge would increase the temperature of the tubes 1, which ensure the dissipation of the thermal energy of the heat-transfer fluid 4 (thermal charge) in the PCM 6; and given that the heat exchanged between the heat-transfer fluid

4 and the tube 1 depends on the temperature gradient between the two, then the temperature increase of the tube 1 will decrease the gradient, even invert it, and would therefore be an obstacle to the thermal charge.

As an example, the distance separating the centre of the tube 1 from the housing 8 respectively containing the heat-transfer fluid 4 and the electrical heat source is at least three times the diameter of the tube 1.

The invention enables an economic and ecological arbitration according to the availability of the calories of the heat network and the electricity of the electrical network. Moreover, in the case of an overproduction of electricity linked to an intense operation of a wind farm, for example, the excess can be enhanced in the form of wind farms, in order to increase the basic production, while enhancing the electrical production in thermal form, during production peaks. Moreover, the network manager can also choose to favour the electrical charge in the case where this would be less expensive than the thermal charge.

The invention also relates to an energy storage method, such as defined in claim 12.

The storage method comprises several phases.

An electrical energy storage phase a), also called electrical charge. During this phase, the electrical resistance 10 operates and the electricity is transformed into heat recovered by the thermal contact agent, if it is present and then exits the profile 7. The heat is then transmitted to the PCM 6, wherein the profile 7 is immersed. The electrical energy is stored in the form of thermal energy.

A thermal energy storage phase b), also called thermal charge. During this phase, the heat-transfer fluid 4 contained in the tube 1 provides heat, which is transmitted to the PCM 6, wherein the tube 1 is immersed. The thermal energy is stored in the form of thermal energy.

An energy destocking phase c), also called thermal discharge. The heat-transfer fluid 4 recovers the heat stored in the PCM 6. The heat-transfer fluid 4 is colder than the PCM 6 which then transmits the thermal energy to the heat-transfer fluid 4.

Advantageously, phases a) and b) can be simultaneous, i.e. that the electrical charge and the thermal charge can be achieved at the same time in the device according to the invention.

The simultaneity of these two phases in particular makes it possible to limit the mechanical stresses of the PCM 6 on the exchanger 5. The invention enables the creation of liquid paths limiting the mechanical stresses on the fins 2, which would be introduced by volume expansion of the PCM 6 during its melting. During phase a), the electrical resistance 10 is in operation. The PCM 6 will melt in the proximity of the wall of the profile 7, creating a liquid path from the bottom of it to the top of the chamber 13. When the PCM 6 melts, it delates and, in the absence of a liquid path, it increases in pressure, which can lead to the damaging of different elements of the device.

Advantageously, the invention makes it possible to achieve an electrical charge while the device is also in the process of being thermally discharged. Steps a) and c) can be simultaneous. In other words, while the cold heat-transfer fluid 4 circulates in the tubes 1, in order to recover the thermal energy stored in the PCM 6, thermal discharge, it is possible to achieve, at the same time, an electrical charge at the electrical resistances. The storage device thus plays the role of a heat exchanger. This method of operation can enable to enhance an available electrical energy. It can also make it possible to ensure a delivery of heat into a substation, even if the heat network is unavailable due to a maintenance or an accident. This type of operation is also similar to the addition of an "electrical power station" on the heat network: indeed, in the case where all the thermal power stations are, as a maximum, of their power, but do not ensure demand, the operation of the different electrical charge means makes it possible to add a heat source onto the network.

Example: Implementation of a storage device according to the invention on an urban heat network.

A storage device according to the invention comprises a PCM 6, finned 2 tubes 1 and a chamber 13, immersion heaters placed in profiles 7 and connected to the electrical network.

For a phase change enthalpy storage system of the finned tube and calender type, it must be relied on, that the inner volume is occupied by around a quarter or a third by the finned tubes. The tubes 1 are made of steel of inner and outer diameters of 20mm and 25.4mm respectively. The aluminium fins 2 of 2.54mm steps, of average thickness 0.4mm and of outer diameter 57.4mm, and the aluminium inserts 3. By considering the insulation of the chamber 13 and the outer coating, then the PCM 6 only represents a little more than half of the total space occupied by the storage device.

If a city of 150,000 inhabitants is considered, the heat network, primary circuit, is crossed by hot water heated up to 180°C, 20 bar.

That is an average substation:

- 75 dwellings served
- 750MWhth supplied over the year
- 150-day heating season (in low season, only the substations ensuring the heating of domestic hot water are in service; mainly the network operates at less than 10% of its total capacity)
- Substations supplied with water heated up to 180°C, 20 bar

MW means Megawatt; MWh means Megawatt hours; MWhthermal means Megawatt hours of thermal source or of discharged thermal energy; MWhelectrical means Megawatt hours of electrical origin.

It is therefore considered that an approximate consumption of $5MWh_{thermal}$/day, $1.5MWh_{thermal}$ of which are consumed during consumption peaks: it is the energy to be stored in the PCM 6. The charge must be done over around 3 hours, that is a desired power of $0.5MW_{thermal}$.

The PCM 6 selected is erythritol:

- Melting point: 120°C
- Melting mass enthalpy: 340kJ/kg
- Constant pressure mass thermal capacity
- Solid density: 1480kg/m^3
- Liquid density: 1300kg/m^3

The total dimensions of such a storage are 2.3m in diameter and 3.0m high for the chamber is 2.9m and 3.3m, insulation included. There are around 100 tubes 1 and at least as many placements for placing immersion heaters in aluminium profiles 7. It is not necessarily necessary to place as many of them; the viewing of which is done on the immersion heater market, thirty seems sufficient. Indeed, knowing that the desired thermal power is $0.5MW_{thermal}$ and that the electrical charge complements it, a maximum electrical power of around $0.25MW_{electrical}$ can be considered, in this case, that is almost 30 immersion heaters of $8kW_{electrical}$. The immersion heaters proposed by Chromalox go up to 3m high and $8kW_{electrical}$, those of Vulcanic go up to 3.2m and $75kW_{electrical}$. The immersion heaters are inserted through the top of the chamber, they are either screwed into the profile 7, or connected to the profile 7 via a flange.

REFERENCES

1. Tube
2. Fins
3. Insert
4. Heat-transfer fluid
5. Exchanger
6. PCM
7. Profile
8. Housing
9. Branching
10. Electrical resistance
11. Fixing means
12. External walls of the insert
13. Chamber

Patentkrav

1. Apparat til lagring af energi ved hjælp af et faseomdannelsesmateriale (MCP), der omfatter et indelukke (13), der er beregnet til at rumme et faseomdannelsesmateriale (6), og en termisk varmekilde, der omfatter et varmeoverføringsmiddel (4), der passerer gennem indelukket (13) og er beregnet til at tilføre varmen til og udtage varmen fra MCP'et (6), hvilket apparat omfatter en i indelukket (13) indrettet elektrisk varmekilde, idet varmeoverføringsfluidet (4), der passerer gennem indelukket (13), er beregnet til at genvinde den varmeenergi, der uden forskel stammer fra den elektriske energi eller fra varmeenergien, **kendetegnet ved, at**

- den elektriske varmekilde er udformet til udelukkende at lagre varmen i MCP'et (6),
- den termiske varmekilde omfatter en veksler (5), der dypper ned i MCP'et (6), og i hvilken varmeoverføringsfluidet (4) cirkulerer,
- apparatet omfatter en profil (7) indrettet i termisk kontakt med MCP'et (6) og i kontakt med veksleren (5), der modtager varmeoverføringsfluidet (4), idet profilet omfatter en holder (8), i hvilken den elektriske varmekilde er placeret,
- apparatet omfatter fastgørelsesmidler mellem mindst en veksler (5) og en profil (7).

2. Apparat ifølge det foregående krav, i hvilket holderen (8) i profilet (7) omfatter et termisk kontaktmiddel, der sikrer varmeledningsevnen mellem den elektriske varmekilde og profilet (7).

3. Apparat ifølge et hvilket som helst af de to foregående krav, i hvilket den elektriske varmekilde er en elektrisk modstand (10).

4. Apparat ifølge et hvilket som helst af de foregående krav, i hvilket veksleren (5) omfatter et rør (1), der omfatter omkredsribber (2), der er udformede til at sikre varmeoverførslen mellem MCP'et (6) og det i røret (1) indeholdte varmeoverføringsfluid (4).

5. Apparat ifølge det foregående krav, i hvilket veksleren (5) omfatter en metallisk indsats (3), der omgiver røret (1) og er udformet til at sikre en varmekontinuitet med røret (1).

6. Apparat ifølge et hvilket som helst af de foregående krav, i hvilket profilet (7) omfatter forgreninger (9), der strækker sig fra holderen (8) i retning mod veksleren (5).

7. Apparat ifølge et hvilket som helst af de foregående krav, der omfatter et antal vekslere (5) og et antal profiler (7), der er indrettede til kontakt med mindst to vekslere (5).

8. Apparat ifølge et hvilket som helst af de foregående krav, i hvilket veksleren (5) og profilet (7) danner en enhed i et stykke, der dypper ned i MCP'et (6) og er beregnet til at rummes i indelukket (13).

9. Apparat ifølge et hvilket som helst af de foregående krav, i hvilket den termiske varmekilde og den elektriske varmekilde er indrettede i afstand fra hinanden for at sikre varmeuafhængighed.

10. Apparat ifølge det foregående krav i kombination med et hvilket som helst af kravene 4 eller 5, i hvilket den termiske varmekilde og den elektriske varmekilde har en afstand fra hinanden på mindst tre gange rørets (1) diameter.

11. Apparat ifølge et hvilket som helst af de foregående krav, i hvilket MCP'et (6) er et flydende/fast MCP.

12. Fremgangsmåde til lagring af energi med et apparat til lagring af varmeenergi ifølge et hvilket som helst af de foregående krav, hvilken fremgangsmåde omfatter:

a- en fase til lagring af elektrisk energi, i hvilken den elektriske varmekilde overfører varmen til MCP'et (6), som lagrer den elektriske energi under danner af varmeenergi,

b- en fase til lagring af varmeenergi, i hvilken varmeoverføringsfluidet (4) fra den termiske varmekilde overfører varmen til MCP'et (6), som lagrer varmeenergien,
c- en fase til udtagning af varmeenergi, der uden forskel stammer fra den elektriske energi eller fra den varmeenergi, der tilvejebringes af varmeoverføringsfluidet (4), i form af varme, i hvilken varmeoverføringsfluidet (4) afkøler MCP'et (6), som frigiver den varmeenergi, som genvindes af varmeoverføringsfluidet (4).

13. Fremgangsmåde ifølge det foregående krav, ved hvilken faserne a- og b- udføres samtidig eller skiftevis.

14. Fremgangsmåde ifølge krav 12, ved hvilken faserne a- og c- udføres samtidig.

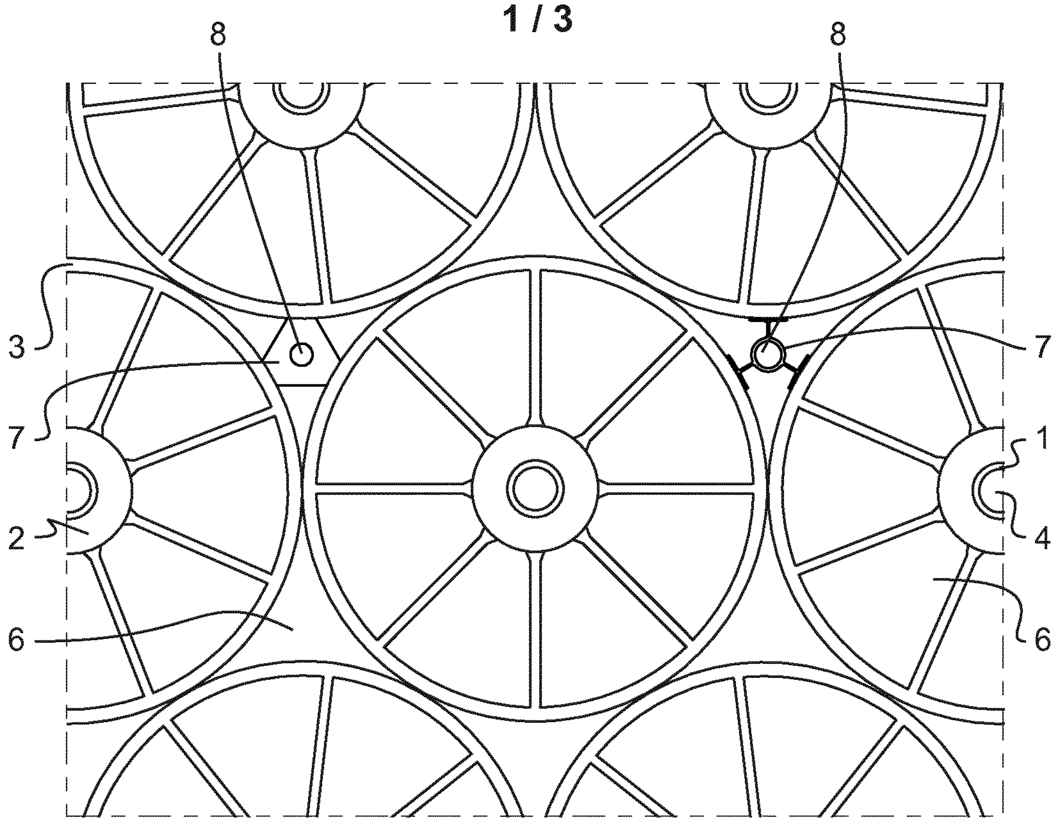

FIG. 1

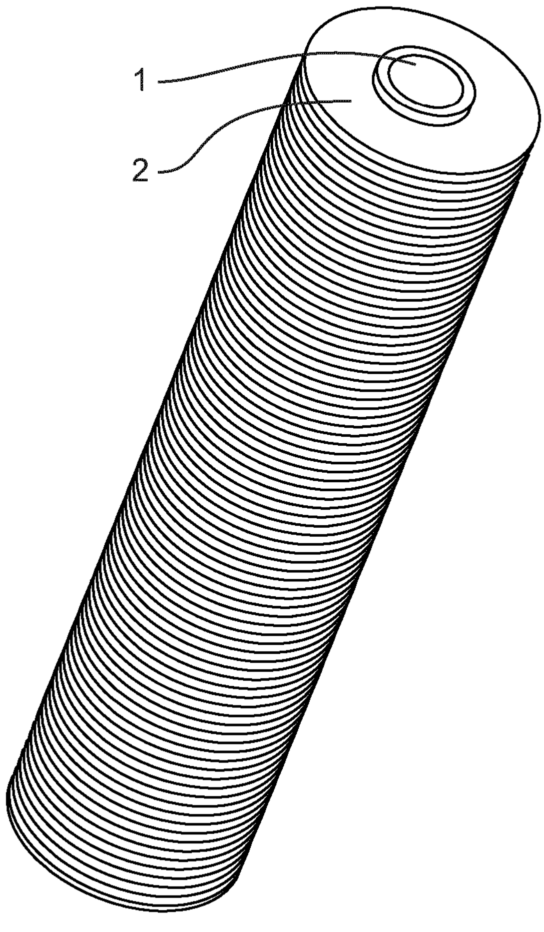

FIG. 2

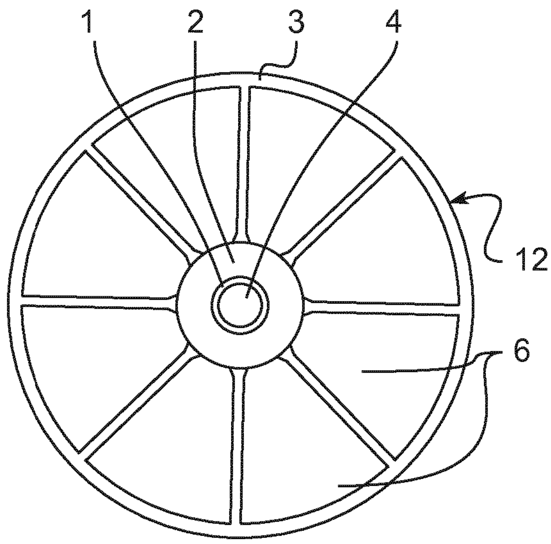

FIG. 3

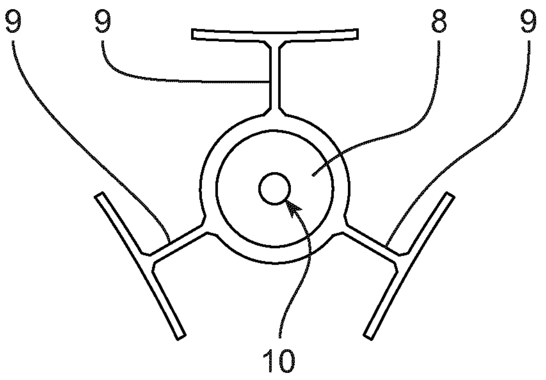

FIG. 4

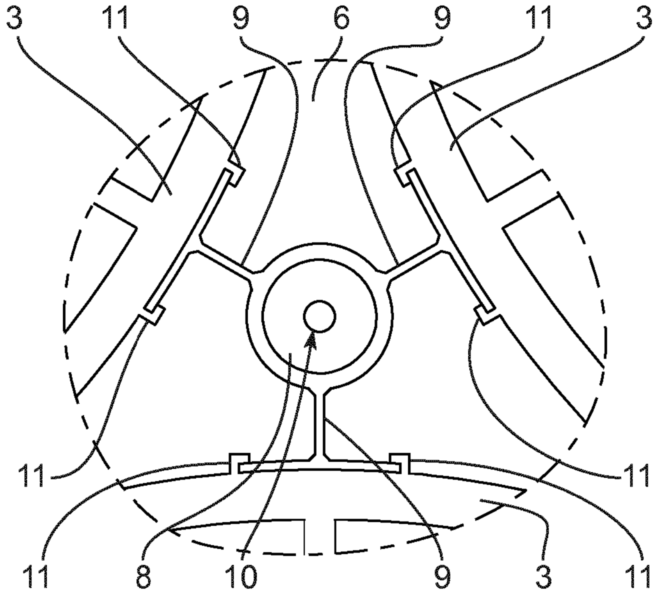

FIG. 5

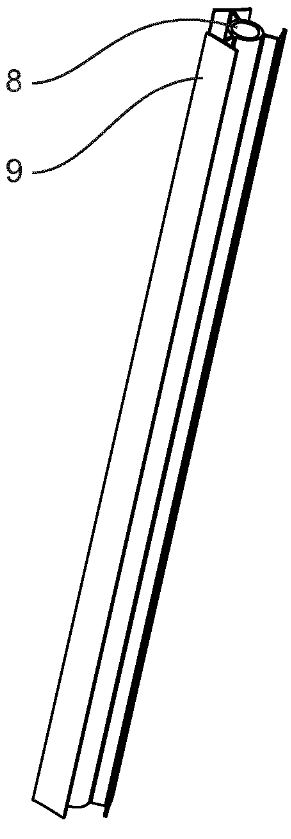

FIG. 6

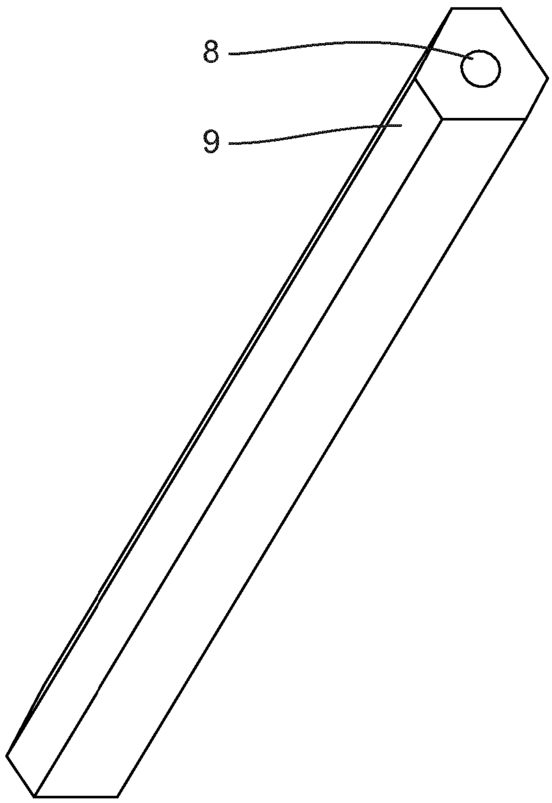

FIG. 7

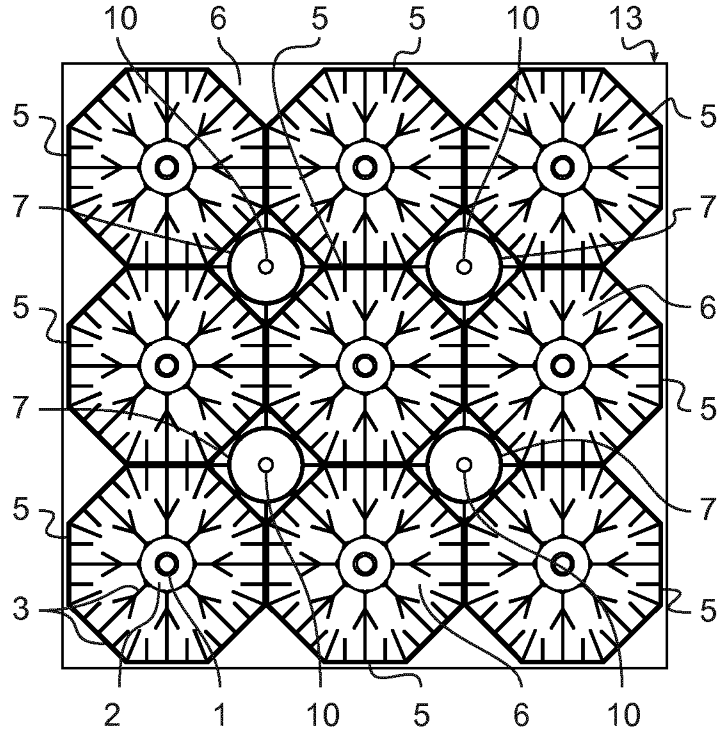

FIG. 8

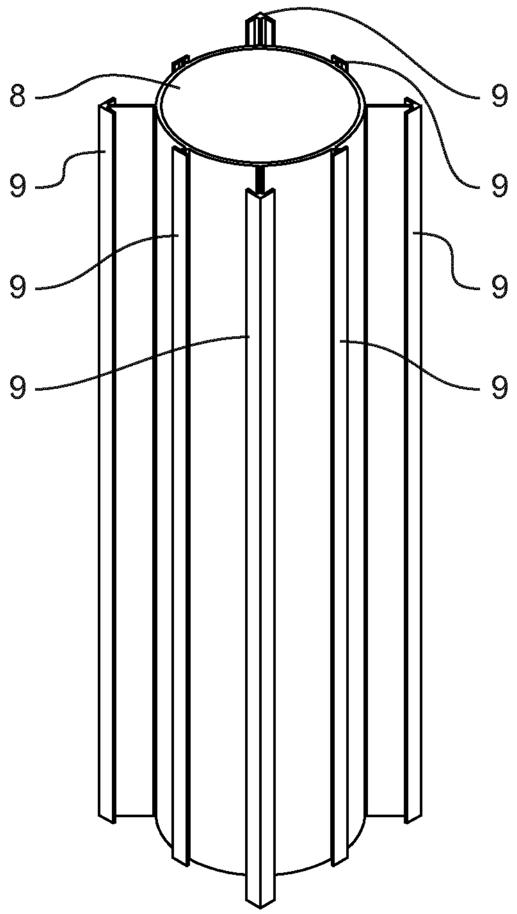

FIG. 9

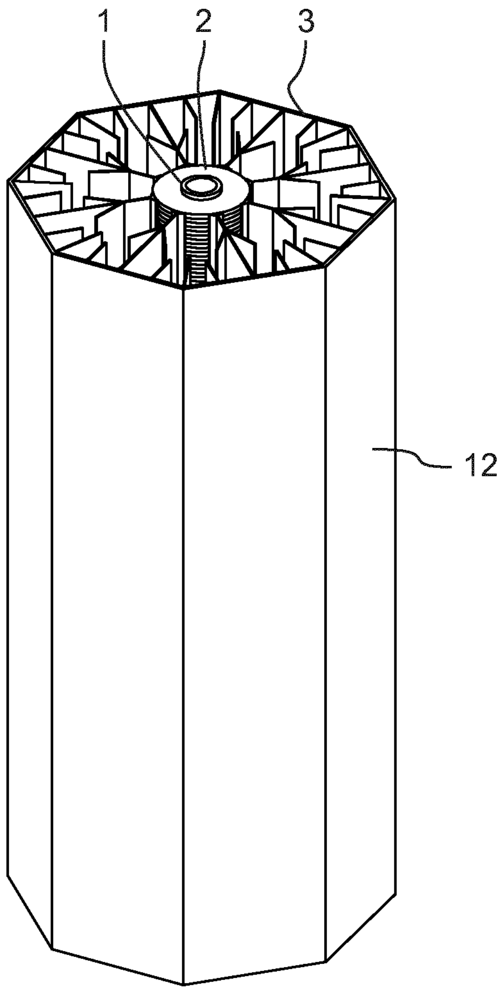

FIG. 10