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

(72) Opfinder: **CHAZELLE, Benjamin, 4 rue Charles Baudelaire, F-38400 Saint-Martin d'Heres, Frankrig**
MARTINELLI, Matthieu, 3 rue Ella Maillart, E110, F-31300 Toulouse, Frankrig
COUTURIER, Raphaël, 12 rue Jean Moulin, F-38360 Sassenage, Frankrig

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

(54) Benævnelse: **SYSTEM OG FREMGANGSMÅDE TIL BESTEMMELSE AF LADNINGSNIVEAUET I ET LATENT VARMELAGER**

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SYSTEM AND METHOD FOR DETERMINING THE CHARGE LEVEL OF A LATENT HEAT STORE

The invention belongs to the technical field of latent heat energy storage.

It relates to a system and a method for determining the charge level of a latent heat energy storage means.

Recall that there are many energy storage means, with this energy able to be stored in particular in mechanical, chemical or thermal form.

Thermal energy storage can be a thermochemical storage, sensible heat storage or a latent heat storage.

To date, the most common means allow for sensitive heat storage, as thermochemical storage means are not yet available at the industrial level.

The invention relates to latent heat storage means that use a phase change material, solid/liquid or solid/solid, of which the phase change is accompanied by a volume variation.

This storage is carried out at a quasi-isotherm temperature corresponding to the phase change temperature.

The quantity of heat that can be stored depends on the mass of the phase change material (or PCM) contained in the storage means as well as the latent heat of the material.

In a latent heat storage means, the solid/liquid phase change material becomes liquid at the time of charge and solidifies during the recovery of the heat.

The storage means with a solid/liquid PCM are preferred over sensitive heat storage means because the quantity of heat stored per unit of volume, or storage density, is greater than that obtained with a sensitive heat storage system.

Consequently, the volumes of storage and of material are reduced, which decreases the price of the system, and limits thermal losses which are proportional to the outer surface of the tank.

In addition, the charges and discharges take place at a constant temperature. The stored heat is released at the same temperature as when it was stored. There is therefore no loss in the quality of the heat stored.

Generally, thermal storage devices are useful for smoothing out the production of an energy production unit by allowing it to function as close as possible to its optimum power.

Indeed, when the energy demand is less than the power supplied by the production unit, the storage means make it possible to store the excess energy produced. On the contrary, when demand is higher than the power supplied by the production unit, the energy is removed from storage.

In practice, the periods of functioning in the nominal regime of the production units are thus extended.

This also makes it possible to reduce the power of each production unit.

In addition, these storage means facilitate the use of renewable but intermittent sources of heat, such as the heat supplied by solar energy.

These means also allow for the recovery and recycling of free energy, i.e. energy that cannot be used as is but which could be recovered and recycled in other processes. Mention can be made in particular of the thermal energy originating from a data centre and which corresponds to the heat that it discharges to cool the servers that it is comprised of.

These means also make it possible to improve the flexibility of the operation by allowing for example the stoppage of a production unit in order to ensure the maintenance thereof.

Finally, they forma a backup means for supplying a network with energy, in the event of failure of a production unit.

The main latent heat storage devices currently being researched are so-called "passive" devices. These devices are comprised of a tank filled by the PCM and passed through by an exchanger that comprises for example a tube bundle.

For a solid/liquid PCM of which the passing from the solid state to the liquid state is accompanied by an increase in volume, during the charge phase (storage), a heat-transfer fluid passes through the tube bundle, it transfers its heat to the PCM which passes from the solid state to the liquid state. During the discharge phase (removal from storage), the heat-transfer fluid still passes through the tube bundle, it takes the heat of the PCM which solidifies.

It should be noted that a solid/liquid PCM can also experience a reduction in volume when it passes from the solid state to the liquid state. This is the case with water which can be used as a PCM for cold storage.

For a cold storage, a PCM solidifies during the charge phase and is liquefied during the discharge phase.

For a passive storage system, the storage material does not have any imposed circulation and the transfer of heat takes place rather through conduction and by natural convection in the liquid phase.

In the specific case of a solid/liquid PCM, the PCM solidifies and strongly attaches itself to the exchange surfaces (tubes or plates), a layer of solid PCM with an increasing thickness covers the walls of the exchanger and insulates them thermally. The creation of this "thermal resistance" results in a rapid decrease in the power exchanged between the heat-transfer fluid and the PCM.

In order to increase the thermal transfer with the PCM, several solutions are implemented. It is for example possible to use an exchanger with fin-tubes tubes or to add a divided material to the PCM that increases the thermal conductivity thereof (metal foam, carbon particles or fibres).

The interest of these so-called passive systems is that the heat-transfer fluid, often under pressure, is confined inside the tube bundle, thus the tank is not pressurised and it is therefore of simple design.

In the rest of the description, reference will be made to latent heat storage devices of the passive type, with these means being promising for heat networks.

However, the invention is not limited to this type of latent heat storage.

It is understood that a thermal storage device can only be used efficiently, in particular by the manager of a heat network, when the thermal energy available in the storage device is known to the latter.

In particular, it is essential to be able to determine if the storage device has to be charged or discharged and to what extent this charge or discharge can be carried out.

In addition, knowing the thermal energy available makes it possible to decide to purchase or to sell the thermal energy in a heat market.

However, determining the thermal energy available in a latent heat energy storage is a problem because the heat is stored at a constant temperature.

Therefore, contrary to a sensitive heat storage device, it is not possible to measure it with temperature sensors.

In a latent heat storage device, the portion of the useful thermal energy that is still available in the device corresponds to the product of the mass of the phase change material that is present in liquid form and of the enthalpy of the mass state change.

In practice, reference is often made to the charge level which corresponds to the portion of useful thermal energy that is still available, divided by the total thermal energy that can be stored in the device.

So by simplifying the expression of the charge level by suppressing the enthalpy of the mass state change, the charge level satisfies the following relationship (1):

$$Tx_{charge} = \frac{m_{PCM/liquid}}{m_{PCM/total}} \qquad (1)$$

where Tx_{charge} is the charge level,

$m_{PCM/liquid}$ is the mass of the PCM in liquid form, and

$m_{PCM/total}$ is the total mass of the PCM contained in the storage device.

The total mass of the PCM is known since it is one of the design and sizing parameters of the energy storage system.

Moreover, the liquid mass of the PCM can be determined easily from the volume occupied by this liquid and from the density of this same liquid.

Several means have already been proposed to evaluate the volume occupied by the PCM in liquid form.

Thus, it has been considered to determine the volume occupied by the PCM in liquid form by determining the positioning of the liquid/solid front in the storage device.

It has been considered to position sensors at different heights of the tank, with these sensors making it possible to indicate the presence of a liquid or solid phase.

This solution was the subject of tests ("Entwicklung eines Messverfahrens zur Bestimmung des thermischen Beladungsgrades von PCMM Paraffin-Speichern", Brandenburgische Technische Universitât Cottbus, Dr. Andreas Donath, Prof. Monika Bauer, 03013 Cottbus, August 2008).

The conclusion of these tests is that, neither the temperature sensors, nor the sensors that measure the difference in conductivity of the medium are suitable.

Indeed, the phase change takes place without a change in temperature.

In addition, the sensors that measure the difference in conductivity of the medium are not sensitive enough.

Sensors that evaluate the optical properties have been retained as the best means for evaluating the state of the PCM at a point.

However, these tests were conducted with a simple panel filled with PCM and intended to cover the walls of a building in order to increase the inertia thereof.

In our case, this determination is not easy because the liquid/solid front is complex.

This results firstly in the architecture of latent heat storage systems that comprise a tank filled by the PCM and passed through by a tube bundle. This also results from the propensity of the PCM to attach itself to the exchange surfaces determined by the tubes, when it solidifies.

Thus, with a storage system that comprises a tank with an exchanger embedded in a mass of PCM, it is suitable to use a substantial number of sensors, which generates many disadvantages.

First of all, maintenance is difficult because the sensors, embedded in the PCM, cannot be removed easily.

It is also suitable to provide substantial means of acquisition, due to the substantial number of sensors.

Finally, this substantial number of sensors has an impact on the measurements taken. Indeed, the sensors modify the internal architecture of the tank and therefore the thermal behaviour thereof.

Mention can also be made of document WO 2012/156343 which proposes to determine the liquid/solid fraction using radar waves.

However, this technique also is not adapted to a single panel filled with PCM, without an embedded exchanger.

It is not suitable for a tank that has an embedded exchanger. Indeed, in this case, the substantial presence of metal generates wave reverberation and adsorption phenomena in such a way that the data cannot be used.

It has also been proposed to determine the volume of PCM in liquid form by measuring the pressure of the ceiling of the tank.

Mention can thus be made of the article "Development of sensors for measuring the enthalpy of PCM storage systems", Gerald Steinmaurer, Michael Krupa, Patrick Kefer, Energy Procedia 48, pages 440-446, 2014.

The ceiling of the tank is defined as the dead volume located in the upper portion thereof.

It is generally comprised of an inert gas in order to prevent any interactions between the PCM and the air that could degrade the properties of the PCM.

The PCM used have a high volume expansion during the melting thereof (about 15%). An increase in pressure therefore takes place in the ceiling between the fully discharged state of the storage (PCM fully solid) and the charged state (PCM fully liquid). It is thus possible to correlate the pressure measured in the ceiling with the liquid fraction formed and therefore to determine the charge level.

In practice, this method based on the measurement of the pressure of the ceiling of the tank does not make it possible to obtain reliable measurements.

Firstly, in order to not oversize the tank, the size of the ceiling has to be minimised. On the contrary, in order to prevent an excessive increase in pressure, the size of the ceiling has to be rather substantial. In the latter two cases, measuring the variation in pressure appears to be disadvantageous: either the ceiling of the tank is oversized, which increases the price of manufacturing the tank and the thermal losses thereof, or the tank is made into a pressurised apparatus, which increases the cost, the regulatory constraints and the dangerousness.

Secondly, it requires a perfect seal of the storage volume in order to be able to observe the change in pressure. Making a completely sealed tank is difficult and expensive because the welds or the mechanical assemblies have to be of very good quality. In addition, these mechanical connections will not remain hermetic over time.

Thirdly, the expansion of the gas under the effect of the temperature has to be taken into account, the change in the temperature of the ceiling must therefore be estimated.

The gaseous ceiling has substantial stratification of the temperatures which is due to the difference in temperatures between the outside and the inside of the tank, combined with the low thermal conductivity of the gas. It is thus difficult to estimate the average temperature thereof.

Finally, quantifying the influence of the expansion of the gas on the increase in pressure seems complicated and would require adding a substantial number of temperature sensors.

The document CH 648 412 proposes another solution for determining the charge level of a latent heat energy storage means, that implements a phase change material (PCM). To this effect, it takes advantage of a measuring fluid and of end limits that make it possible to determine if the PCM is charged or discharged. The solution proposed in this document does not however make it possible to determine the charge level of the PCM, whatever the charge state of the PCM.

The invention has for object to overcome these disadvantages by proposing a system and a method that makes it possible to easily and reliably determine the charge level of a latent heat energy storage means.

In particular, the invention has for object to propose such a system and method that makes it possible to determine this charge level whatever the charge state of the latent heat energy storage means.

This system and this method apply to a storage means that comprises a tank partially filled with a phase change material of which the phase change is accompanied by a volume variation with a heat exchanger embedded in said material, with this storage means being in a fully discharged state when the phase change material is substantially totally in a first state and in a fully charged state, when the phase change material is substantially totally in a second state.

According to the invention, the system comprises:

- a measuring fluid intended to be poured in the tank of the storage means,

- means for measuring the height of the fluid in the tank, and

- means for calculating the charge level of the storage means at a determined moment of its functioning, according to the difference between the height of the fluid present in the tank when the storage means is fully discharged and the height of the fluid at said determined moment.

In a first alternative, the phase change material is in solid form in said first state and in said second state.

In a second alternative, the phase change material is in solid form in said first state or in said second state and in liquid form in said first state or in said second state and the measuring fluid is compatible and non-miscible with the phase change material.

The fluid advantageously comprises a density less than that of the phase change material in liquid form.

The system comprises a sufficient quantity of measuring fluid in such a way that the free surface of the measuring fluid is flat whatever the charge state of the latter.

Thus, as an indication, the volume of said measuring fluid is, preferably, at least equal to the volume variation of the phase change material during the melting thereof.

The means for measuring can advantageously consist in a laser telemeter, an optical level sensor or an instrumented float.

The invention also relates to a method for determining the charge level of a latent heat energy storage means.

According to the invention, the method comprises the following steps:

(a) filling the tank of the storage means with a measuring fluid,

(b) carrying out a complete discharge of the storage means

(c) measuring the height of the fluid in the tank when the storage means is in this fully discharged state,

(d) measuring the height of the fluid in the tank at a determined moment of the functioning of the storage means, and

(e) calculating the charge level at said determined moment according to the difference between the heights of the fluid measured in steps (c) and (d).

In a first alternative, the phase change material is in solid form in said first state and in said second state.

In a second alternative, the phase change material is in solid form in said first state or in said second state and in liquid form in said first state or in said second state.

Preferably, the measuring fluid used is then compatible and non-miscible with the phase change material and its density is less than that of the phase change material in liquid form.

The volume of the measuring fluid poured in the tank is advantageously chosen in such a way that the measuring fluid has a flat free surface, whatever the charge state of the storage means.

Thus, as an indication, the volume of the measuring fluid poured in the tank of the storage means is at least equal to the volume variation of the phase change material during the melting thereof.

Preferably, the tank is filled with the phase change material, in liquid phase, before step (a).

The invention will be understood better and other purposes, advantages and characteristics of the latter will appear more clearly when reading the following description and which is given in regard to the accompanying drawings wherein:

- figure 1 is a diagrammatical view in a longitudinal cross-section of a latent heat storage means equipped with the system according to the invention, the tank being in a fully discharged state, and

- figure 2 is a view similar to figure 1, wherein the tank is in a partially charged state.

The elements that are common to the two figures will be designated by the same references.

Figure 1 shows a storage means comprising a tank 1 and an exchanger 2 as well as a certain quantity of a phase change material 3. This here is a solid/liquid phase change material of which the passage from the solid state to the liquid state is accompanied by a volume increase.

The exchanger 2 includes several tubes 20, wherein the transfer fluid circulates and plates or fins 21 distributed along these tubes 20.

In the example shown in figure 1, the exchanger comprises several rows of three tubes, with these rows being substantially parallel and the tubes being aligned from one row to the other. The number of rows and the number of tubes per row are defined during the sizing of the storage means.

Other arrangements of the tubes can be considered. Thus, the tubes can be offset from one row to the other in order to create a staggered arrangement.

This storage means is equipped with the system for determining the instantaneous thermal energy according to the invention.

It comprises a measuring fluid 4 which was poured in the tank 1, as well as a level sensor 5 which is here arranged in the upper portion of the tank 1.

In figure 1, the storage means is shown in a fully discharged state. In other terms, the phase change material is substantially totally in a solid state.

Preferably, the volume of the measuring fluid is chosen in such a way that it fully covers the fins 21 of the exchanger, whatever the charge state of the storage means.

In this way, the measuring fluid 4 has a free surface 40 that is flat.

H_0 denotes the height of the measuring fluid in the tank, i.e. the distance between the free surface 40 of the measuring fluid and the bottom 10 of the tank.

This height H_0 corresponds to the initial functioning condition of the latent heat storage means.

The measuring fluid must be compatible and non-miscible with the PCM.

The compatibility between the measuring fluid and the PCM translates into the fact that these two products must not chemically react together. Regarding the non-miscibility, the mixture has to be heterogeneous and there must not be any emulsion at the interface. That is why the measuring fluid will be, preferably, considerably less dense than the liquid PCM. Indeed, this difference in density avoids the phenomena of a mixture that can lead to an emulsion. The measuring fluid will therefore remain in the upper portion of the tank.

In addition, as the measuring fluid is in the tank, it is liable to be heated. It is therefore necessary that the fluid not deteriorate with the temperature, or that it is vaporised. The evaporation temperature must therefore be judiciously chosen according to the operating conditions.

Moreover, the measuring fluid will be able to store and transfer energy. Therefore it is interesting to select a fluid that has a high thermal capacity, in order to optimise the energy density of the storage system.

Finally, it is desirable that the measuring fluid not chemically react with the other materials that are present (tube, fins), or that it oxidises in contact with air.

Preferably, when the measuring fluid is poured in the tank 1, the PCM is present in liquid form in the tank.

When the measuring fluid has been poured, a full discharge of the storage means is carried out, in such a way that the PCM is substantially totally in a solid state, as shown in figure 1. It is preferable to proceed as such in order to prevent the presence of air cavities in the PCM in solid form, during the measurement of Ho corresponding to the initial functioning condition. Indeed, the presence of these cavities would generate an error with this measurement.

This step of calibration can be carried out periodically during the implementation of the method.

It has for object to initialise the functioning of the system at the first time it is put into operation or after the occurrence of an event that may have modified the structure of the storage means, for example maintenance on an insert or verification of the internal welds. The purpose is to have the most precise measurement all throughout the life of the system.

The sensor 5 makes it possible to measure the level of the free surface 40 of the fluid 4 and therefore, in the discharged state of the storage means, the height Ho.

This sensor 5 can in particular be a laser telemeter. Mention can be made for example of a short-range distance sensor marketed by the company SICK, of which the resolution is comprised between 2µm and 90µm with a measurement range of up to 1 m.

Reference can also be made to the laser telemeter marketed by the company Parallax of which the measurement range is comprised between 15 cm and 122 cm, with a precision of 3%.

Other examples of sensors could be used, for example an optical level sensor or an instrumented float.

During the functioning of the latent heat storage means, a variation in the level of the free surface of the measuring fluid can be caused by three phenomena:

- the increase or the decrease in the temperature of the measuring fluid causing a change in the volume thereof,

- the increase or the decrease in the temperature of the liquid PCM resulting in a change in the volume thereof,

- the melting or the solidification of the PCM.

The first two phenomena are based on the variation with the temperature of the density of these two liquids. They can be quantified thanks to very few temperature measurements, even neglected due to the quasi iso-temperature of the storage. In fact, latent storages carry out only a heating of a few degrees Celsius above the melting temperature of the PCM, which represents a low expansion of the liquid PCM. For increased clarity and for simplification, these two phenomena will not be taken into account in the examples of calculations.

The last phenomenon is the one that we are seeking to quantify. It will be shown hereinbelow that it is possible to establish a law that provides the charge state according to the level of the measuring fluid.

Figure 2 shows the storage means in a partially charged state.

It shows a portion of the PCM in solid form was transformed into liquid. The portion of the PCM in solid form is identified by reference 30 and the portion of the PCM in liquid form is identified by reference 31.

The sensor 5 makes it possible to determine the height of the free surface of the liquid present in the tank or the distance between the free surface 40 of the measuring fluid 4 and the bottom 10 of the tank at a determined instant t of the functioning of the storage means. This distance is identified by the reference H_t.

Figures 1 and 2 show that, in the example shown, a free space subsists between the free surface 40 of the measuring fluid and the upper portion of the tank.

As indicated hereinabove, this dead volume is commonly referred to as "ceiling of the tank".

However, the invention is not limited to this embodiment and the tank may not include any dead volume.

Moreover, the tank can be designed to be hermetic.

However, the invention is not limited to this embodiment and the tank could be in communication with the outside environment by means of a vent provided in the top portion.

This embodiment makes it possible to prevent a rise in pressure inside the tank.

The increase in the volume of the measuring fluid as well as that of the liquid PCM under the effect of the charge (thermal expansion) is low. On the other hand, these volume increases can be taken into account thanks to a temperature measurement and integrated into the following expressions, but for increased clarity, these terms are not mentioned. On the other hand, the volume occupied by the PCM in liquid form is greater than the volume corresponding to the PCM in solid form, in such a way that the height H_t is greater than the height H_0.

It is possible to determine the mass of the PCM in liquid form in the following way.

First of all, the expansion coefficient of the PCM during the solid-liquid transition thereof is obtained by the relationship (2):

$$\left(1 - \frac{\rho_{PCM\,liquid}}{\rho_{PCM\,solid}}\right) \qquad (2)$$

where:

• $_{PCM\,liquid}$ is the volume density of the liquid PCM (expressed in Kg/m^3) and

• $_{PCM\,solid}$ is the volume density of the solid PCM (expressed in Kg/m^3).

It is therefore possible to express the additional volume occupied by the volume of the PCM in liquid form by multiplying this volume by son expansion coefficient:

$$V_{expansion} = V_{PCM/liquid} \times \left(1 - \frac{\rho_{PCM\,liquid}}{\rho_{PCM\,solid}}\right) \qquad (3)$$

where:

$V_{expansion}$ is the volume increase that takes place during a charge (expressed in m^3), and

$V_{PCM/liquid}$ is the volume occupied by the liquid PCM (expressed in m^3).

The additional volume can also be expressed by the relationship (4) which makes use of the measurement of the level of the fluid in the tank:

$$V_{expansion} = \left[\left(H_t - H_0 \right) \times S_{average} \right] \qquad (4)$$

where:

H_t is the height of the free surface of the fluid at time t of the functioning of the storage means, the storage means being partially charged (expressed in m),

H_0 is the height of the free surface of the fluid when the storage means is in a fully discharged state (expressed in m) and

$S_{average}$ is the free section of the tank taking account of the presence of the exchanger (expressed in m^2),

By combining relationships (3) and (4), the relationship (5) is obtained:

$$V_{PCM/liquid} \times \left(1 - \frac{\rho_{PCM\ liquid}}{\rho_{PCM\ solid}} \right) = \left[\left(H_t - H_0 \right) \times S_{average} \right] \qquad (5)$$

Thus, the volume occupied by the liquid PCM is defined by the relationship (6):

$$V_{PCM/liquid} = \frac{\left[\left(H_t - H_0 \right) \times S_{average} \right]}{\left(1 - \frac{\rho_{PCM\ liquid}}{\rho_{PCM\ solid}} \right)} \qquad (6)$$

Taking account of the relationship (1) defined hereinabove, the charge level can be expressed by the relationship (7):

$$Tx_{charge} = \frac{V_{PCM/liquid} \times \rho_{PCM\ liquid}}{m_{PCM/total}} \qquad (7)$$

where

$V_{PCM/liquid}$ is the volume occupied by the liquid PCM (expressed in m^3),

$\bullet_{PCM\,solid}$ is the volume density of the solid PCM (expressed in Kg/m^3), and

$m_{PCM/total}$ is the total mass of the PCM contained in the storage device (expressed in Kg).

Taking account of the relationship (6), the charge level can therefore also be expressed in the form of the relationship (8):

$$Tx_{charge} = \frac{(H_t - H_0) \times S_{average} \times \rho_{PCM\ liquid}}{\left(1 - \frac{\rho_{PCM\ liquid}}{\rho_{PCM\ solid}}\right) \times m_{PCM/total}} \qquad (8)$$

Thus, the system according to the invention can make it possible to determine the mass of the liquid PCM present in the tank and therefore, the portion of useful thermal energy that is still available as well as the charge level at an instant t of the functioning of the storage means, by allowing for the measurement of the increase in volume caused by the expansion of the PCM during the melting thereof.

It is understood that the volume of the liquid PCM as the charge level are directly linked to the measured height of the free surface of the measuring fluid. It is sufficient to connect the sensor to an acquisition processor or an Arduino card for example, in order to be able to retrieve and process the information. A data teletransmission via ADSL or GPRS to the manager of the network allows for the control of the charge state and the optimisation of the network according to the different storage means equipped with the system according to the invention.

It can also be noted that the system according to the invention makes it possible to reveal certain malfunctions, by detecting an abnormal change in the level of the measuring fluid or an excessive change in the level (level of the fluid that falls below a low level (Ho), or level of the fluid that exceeds the maximum level).

Thus, an excessively rapid increase in the normal limit of the level or the exceeding of this normal limit can indicate a leak of heat-transfer fluid from the inside of the tubes of the embedded exchanger to the storage medium.

Moreover, an excessively rapid drop and/or below a low limit could indicate a leak of the tank containing the PCM, which would flow to the outside of the tank.

This means of detecting leaks is interesting because it can occur that a leak is difficult to detect.

The preceding description relates to a storage means of which the tank is partially filled with a solid/liquid PCM of which the passing from the solid state to the liquid state is accompanied by a volume increase.

The invention is not however limited to this embodiment.

Thus, the PCM contained in the tank could be a solid/liquid PCM of which the passing from the solid state to the liquid state is accompanied by a volume decrease. This is in particular the case when the PCM is water, the storage means being a cold storage.

Moreover, the PCM contained in the tank could also be a solid/solid PCM, of which the passing from a first solid state to a second solid state is accompanied by a variation in volume.

In this respect it is possible to mention as an example of a PCM of this type, Pentaerythritol.

Solid/solid PCMs can be used in the framework of the invention because their variation in volume during the passing from one solid state to the other is sufficiently substantial.

Generally, the variation in volume of a solid/solid PCM is comprised between about 5 and 10%. It is about 10% for Pentaerythritol. It is less than that which is observed for solid/liquid PCMs, as paraffins for which the volume variation is about 15%. It however allows for the implementation of the method according to the invention.

It is understood that the system according to the invention can have many applications. It can in particular be used in association with storage means for a concentrated solar power plant with direct steam generation, for urban heat networks and for systems for recovering free heat in household waste incineration plants.

An embodiment of a system according to the invention shall now be described that makes it possible to determine the useful thermal energy available or the charge level of a latent storage means intended for a sub-station of a heat network.

Sub-stations are the delivery points of the heat to the subscriber. They allow for the transfer of heat between the primary distribution network and the secondary network which serves the users.

Over a heat network, consumption peaks typically represent 30% of the thermal consumption of a typical heating day. They are provided by turning on boilers that function with gas or heavy fuel oil, which pollute and with a high cost of energy.

It can then be considered to replace these boilers with a local solar thermal production. This production will be stored in latent heat storage and released during consumption peaks. This storage can also be charged by the recovery of local free heat (data centre, household waste incineration plant, etc.). Choosing a latent storage is obvious due to the low amount of space available in the urban environment. Indeed, thanks to their compactness, these storages can be installed on a roof, in the basement, on the public road or in the lower portion of the double skin of a building.

It can be considered that a typical sub-station has the following characteristics:

• 75 housing units served,

• 750 MWh_{th} supplied over the year,

• 150 heating days at high power

• supply of the sub-station with superheated water (up to 180°C, 20 bar) which forms the fluid circulating in the exchanger of the storage means.

The tank of the latent heat storage means is defined in the following way, taking account of the present technologies:

- the exchanger placed in the tank represents about 20% of the interior volume of the tank,

- the mass of the PCM represents about 70% of the interior volume of the tank.

It is in particular possible to choose, as a PCM, a polyol, for example erythritol which has the following characteristics:

• melting temperature: 120°C,

• latent heat of melting-solidification: 340 kj/kg,

• solid density: 1480 kg/m^3,

• liquid density: 1300 kg/m^3,

The system according to the invention comprises a measuring fluid which is a refined mineral oil marketed by the company Shell under the name Shell heat transfer oil S2X.

Its density at 15°C is 865 kg/m^3.

Moreover, this oil is non-miscible and compatible with the erythritol, as confirmed in document "Experimental study on the direct/indirect contact energy storage container in mobilized thermal energy system (M-TES)", Applied Energy 119 (2014) 181-189.

The volume of the measuring fluid satisfies the relationship (9):

$$V_{Measuring\ fluid} = V_{PCM\frac{total}{liquid}} \times \left(1 - \frac{\rho_{PCM\ liquid}}{\rho_{PCM\ solid}}\right) \quad (9)$$

where:

$V_{Measuring\ fluid}$ is the volume of the measuring fluid,

$V_{PCM\frac{total}{liquid}}$ is the total volume of PCM in its liquid state, and

$\left(1 - \frac{\rho_{PCM\ liquid}}{\rho_{PCM\ solid}}\right)$ is the expansion coefficient of the PCM during the solid-liquid transition corresponding to the relationship (2).

In the example defined hereinabove, the relationship (9) is expressed in the following way;

$$V_{Measuring\ fluid} = 12.3 * \left(1 - \frac{1300}{1480}\right)$$

or a volume of measuring fluid equal to 1.5 m^3.

Of course, the invention is not limited to this embodiment and other PCM/measuring fluid pairs can be used.

Thus, it is possible to use water as a measuring fluid with paraffins as a PCM, a thermal oil (polychlorinated biphenyl) as measuring fluid with a salt hydrate as a PCM, or a refined mineral oil with a polyol.

By way of example, the thermal oil of the polychlorinated biphenyl type can be the thermal oil marketed under the name Therminol VLT by the company Eastman Chemical Company.

Since most PCMs have a melting temperature comprised in the temperature range 0 to 175°C, the Therminol VLT oils is less dense than the PCMs in their liquid state. In addition, the oils are most of the time non-miscible and compatible with the other fluids.

Thus, the system and the method according to the invention make it possible to measure the instantaneous thermal energy or the charge level of most of the passive latent energy storage means, without any notable modification of these storage means.

Moreover, this system and this method allow for instantaneous determinations via a simple measurement of the level and without knowing the operating history of the storage means and without influence of external conditions. Contrary to what was presented in the prior art, the thermal losses do not have to be quantified, they can be measured directly by following the level of the fluid in the tank.

The invention is well suited for heat storage means where the instrumentation has to be limited for cost reasons.

In addition, the determining of the instantaneous thermal energy or of the charge level of the latent heat storage means is carried out efficiently, reliably and precisely.

The system and the method according to the invention can be used whatever the technology used to improve the thermal transfers, whether it is fins, matrices, particles or foams.

Finally, the invention makes it possible to overcome the use of an inert ceiling. In fact, the measuring fluid creates a barrier between the PCM and the ceiling of the tank. Using a ceiling comprised of an inert gas in order to prevent any interactions between the PCM and the air that could degrade the properties of PCM is therefore not required. In addition, the tank is not necessarily hermetic and under pressure.

Patentkrav

1. System til bestemmelse af ladningsniveauet for et middel til lagring af latent varmeenergi, idet lagringsmidlet omfatter en beholder, der er delvis fyldt med et faseskiftende materiale, hvis faseskift ledsages af en rumfangsændring, med en varmeveksler nedsænket i materialet, idet dette lagringsmiddel er i en fuldstændig afladet tilstand, når det faseskiftende materiale er i det væsentlige fuldstændigt i en første tilstand, og i en fuldstændig ladet tilstand, når det faseskiftende materiale er i det væsentlige fuldstændigt i en anden tilstand, omfattende:

- et målefluid (4) beregnet til at hældes i beholderen (1) til lagringsmidlet, og **kendetegnet ved, at** systemet omfatter
- midler til måling (5) af højden af målefluidet i beholderen, og
- midler til at beregne lagringsmidlets ladningsniveau i et bestemt øjeblik af dets drift som funktion af forskellen mellem højden af fluidet, der findes i beholderen, når lagringsmidlet er fuldstændig afladet, og højden af fluidet i det bestemte øjeblik.

2. System ifølge krav 1, **kendetegnet ved, at** det faseskiftende materiale er i fast form i den første tilstand og i den anden tilstand.

3. System ifølge krav 1, i hvilken det faseskiftende materiale er i fast form i den første tilstand eller i den anden tilstand og i flydende form i den første tilstand eller i den anden tilstand, **kendetegnet ved, at** målefluidet er forligeligt og ublandbart med det faseskiftende materiale.

4. System ifølge krav 3, **kendetegnet ved, at** målefluidet har en lavere vægtfylde end det faseskiftende materiales i flydende form.

5. System ifølge et af kravene 1 til 4, **kendetegnet ved, at** målefluidets rumfang er valgt således, at målefluidet har en plan fri overflade (40) uanset lagringsmidlets ladetilstand.

6. System ifølge et af kravene 1 til 5, **kendetegnet ved, at** målemidlerne (5) kan bestå af en laserafstandsmåler, en optisk niveausensor eller endda en instrumenteret svømmer.

7. Fremgangsmåde til bestemmelse af ladningsniveauet for et middel til lagring af latent varmeenergi, idet lagringsmidlet omfatter en beholder, der er delvis fyldt med et faseskiftende materiale, hvis faseskift ledsages af en rumfangsændring, med en varmeveksler nedsænket i materialet, idet dette lagringsmiddel er i en fuldstændig afladet tilstand, når det faseskiftende materiale er i det væsentlige fuldstændigt i en første tilstand, og i en fuldstændig ladet tilstand, når det faseskiftende materiale er i det væsentlige fuldstændigt i en anden tilstand, **kendetegnet ved, at** fremgangsmåden omfatter følgende trin:

(a) at fylde beholderen (1) til lagringsmidlet med et målefluid (4),

(b) at foretage en fuldstændig afladning af lagringsmidlet,

(c) at måle højden af fluidet i beholderen, når lagringsmidlet er i den fuldstændigt afladede tilstand,

(d) at måle højden af fluidet i beholderen i et bestemt øjeblik under lagringsmidlets drift og

(e) at beregne ladningsniveauet i det bestemte øjeblik som funktion af forskellen mellem de i trin (c) og (d) målte højder af fluidet.

8. Fremgangsmåde ifølge krav 7, **kendetegnet ved, at** det faseskiftende materiale er i fast form i den første tilstand og i den anden tilstand.

9. Fremgangsmåde ifølge krav 7, i hvilken det faseskiftende materiale er i fast form i den første tilstand eller i den anden tilstand og i flydende form i den første tilstand eller i den anden tilstand, **kendetegnet ved, at** det anvendte målefluid er forligeligt og ublandbart med det faseskiftende materiale.

10. Fremgangsmåde ifølge krav 9, **kendetegnet ved, at** målefluidets vægtfylde er lavere end det faseskiftende materiales i flydende form.

11. Fremgangsmåde ifølge et af kravene 6 til 8, **kendetegnet ved, at** målefluidets rumfang er valgt således, at målefluidet har en plan fri overflade uanset lagringsmidlets ladetilstand.

12. Fremgangsmåde ifølge et af kravene 9 til 11, **kendetegnet ved, at** beholderen (1) før trin (a) er fyldt med det faseskiftende materiale i flydende fase.

Fig.1

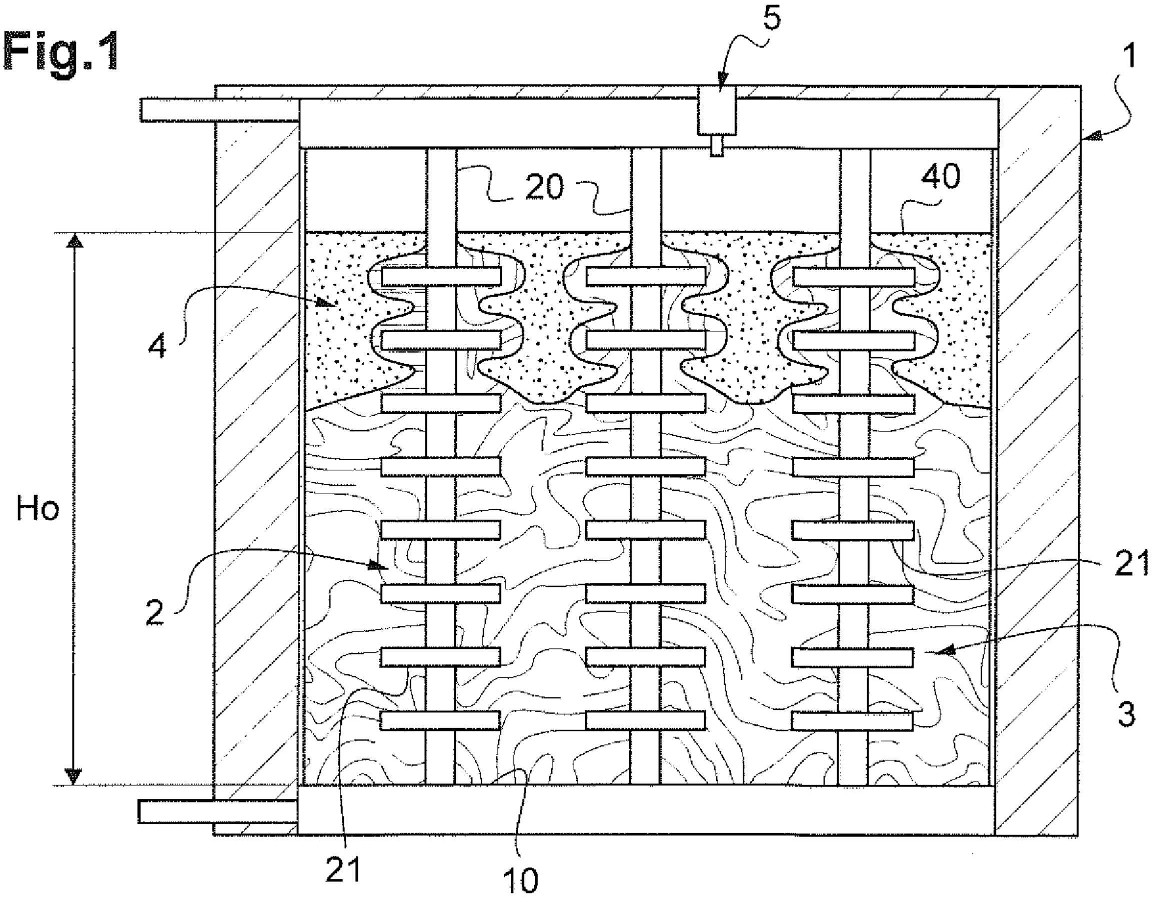

Fig.2