ENERGY STORAGE THROUGH THE USE OF PHASE CHANGE MATERIALS (PCM) IMPLEMENTATION AND EVALUATION OF LATENT STORAGE TANKS FOR ECONOMICAL HEAT STORAGE

Stephan THALER, Robert HAUSER

ABSTRACT

Due to fluctuating electricity networks (electricity generation from wind, photovoltaic...) it will be increasingly important in the future to perform network smoothing. This should be done on smart grids. Once electricity is not storable, it may be a good idea to produce heat at current excess and store it.

Currently, water is still considered as the most appropriate storage medium. Furthermore, there are also latent heat storage materials such as zeolite (only at high temperatures) or salt mixtures (e.g. sodium acetate) available. Also paraffin and other materials in which a phase change (liquid to solid) takes places are available. These stores have at present, however, the problem of heat conduction within the storage mass.

It is now scheduled to integrate suitable PCM-tanks into an existing heat pump system. The modified system should be able to store the excess energy and to recirculate it into the heating system. This should lead to an economically use of the heating pump and also to compensate the fluctuating power generation. As a significant parameter in this case the influence of the charging and discharging times is considered. The expected results should provide innovative heat storage methods to overcome these new challenges.

1. INTRODUCTION

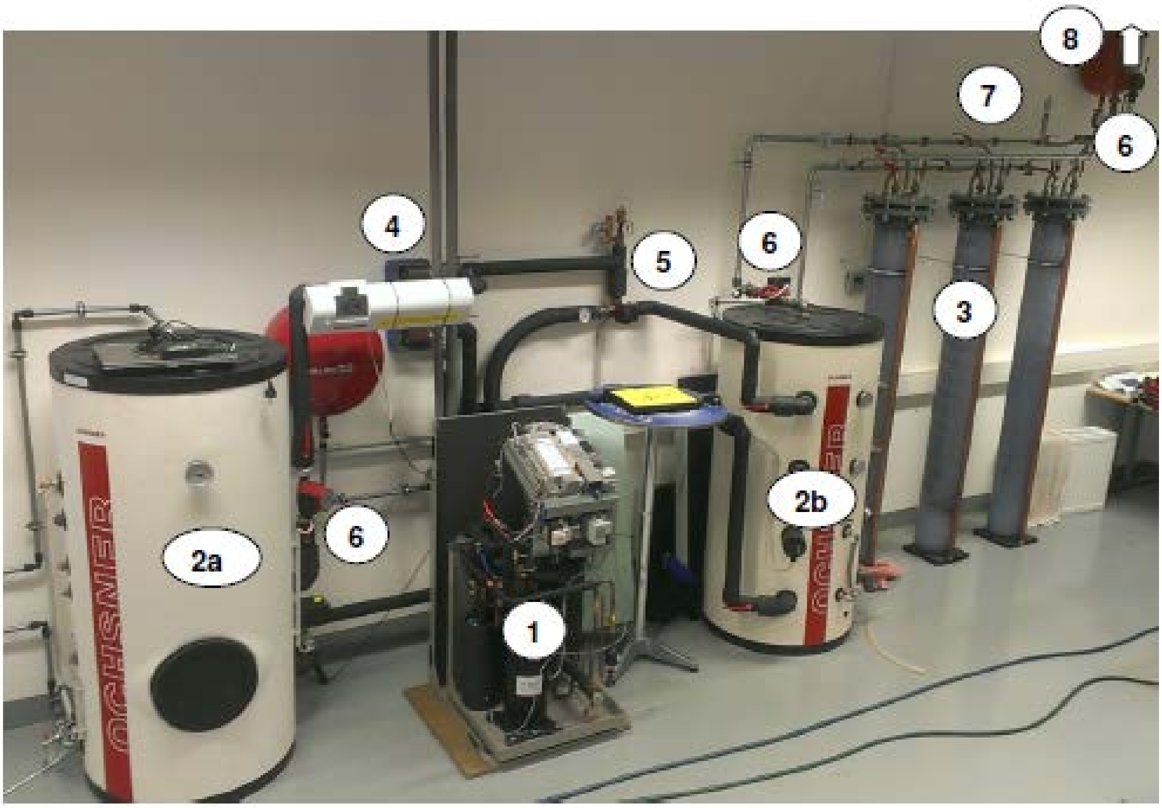
Within the project, a heat pump unit was rebuilt in the laboratory and adapted to allow an implementation of latent heat storage. Furthermore, appropriate test setups were integrated to operate and evaluate the storage systems. The research work concerning the appropriate latent heat storage systems and their interpretation and evaluation was carried out as part of bachelor theses. There are two selected types of PCM-tanks integrated in the recent structure of the system. The energy measurement is performed by heat meters, temperature measurements, and flow meters.

This structure enables a detection of the charge and discharge of the latent heat storage as well as a verification of the calculations and data sheets with the real measured values.

The evaluation of the test results provides a classification of the different storage media and the suitable fields of use, depending on the operating parameters.

2. EXPERIMENTAL SETUP

The following figure shows the test system which is constructed in the laboratory. This experimental setup is used to verify the theoretical results.



1… heating pump
2a… boiler
2b… buffer
3… paraffin tank
4… heat exchanger
5… mixing valve
6… circulation pump
7… vent valve
8… radiator

Fig. 1: Existing test setup [1]

The pilot plant was expanded following the new requirements. In this experimental setup different types of PCM-tanks were integrated and equipped with appropriate measuring and control devices to enable an evaluation of the various storage types. As a reference, the existing traditional buffer is used.

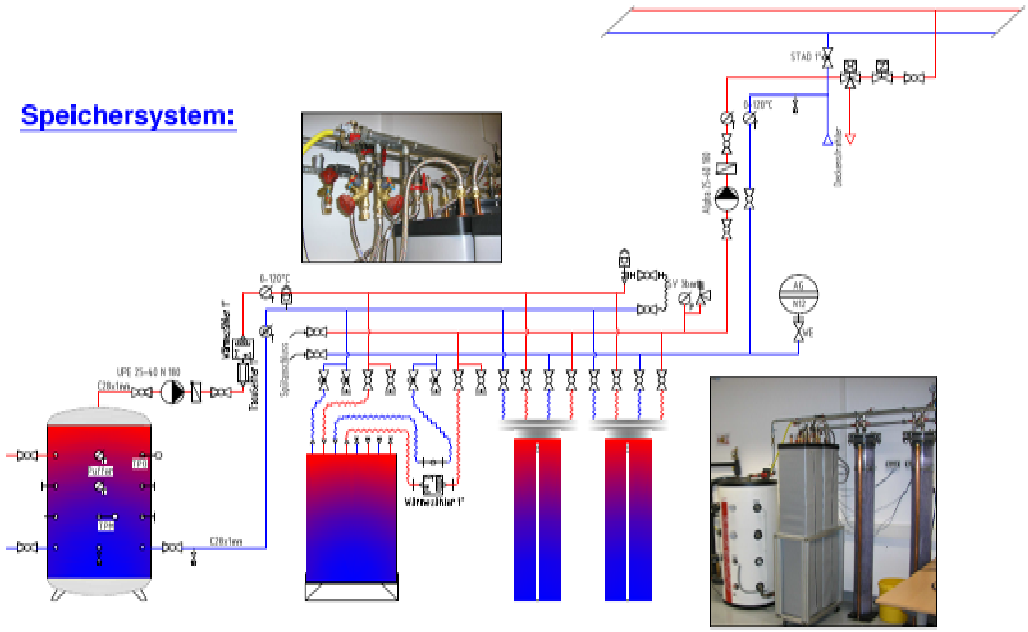


Fig. 2: New test setup

As a representative of inorganic latent heat storage heat-battery PCMX was selected. This heat battery uses a sodium acetate Trihydrat mixture as a heat storage medium. The main advantage of the thermal battery in comparison to traditional buffer is a much higher thermal capacity per unit mass of the heat storage substance in the temperature section 55-60 ° C. The difference can be seen by the following diagram. [2]

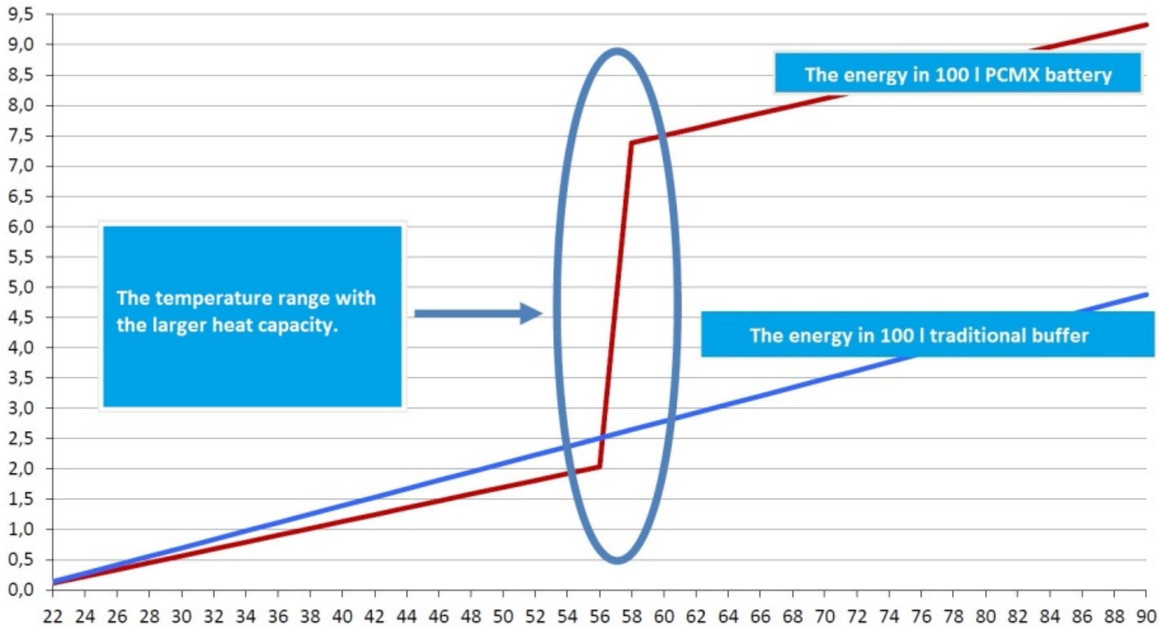


Fig. 3: Comparison of stored energy: PCMX and traditional buffer [2]

During the heating of the medium in the temperature range 55-60°C, a phase transition occurs, this means the change in the aggregate state of a solid in a liquid. The battery is initially charged up to the temperature of 50°C. As in the range up to 50 °C, the sodium acetate Trihydrat has a smaller heat capacity than water; the battery is heated faster than a traditional buffer. In this stage of the work, the heat-retaining substance remains in the solid state. In the temperature range of 50-65°C, the battery stores more energy through the use of the phase transition. According to the manufacturer may take place in this temperature range, an 8 -fold higher energy storage than the storage medium of water.

During the discharge, the phase transition is inverted. The heat-storing liquid changes physical state from liquid to solid. A discharge of the battery can be up to a temperature of 45°C. The following figure shows this functional principle. [2]

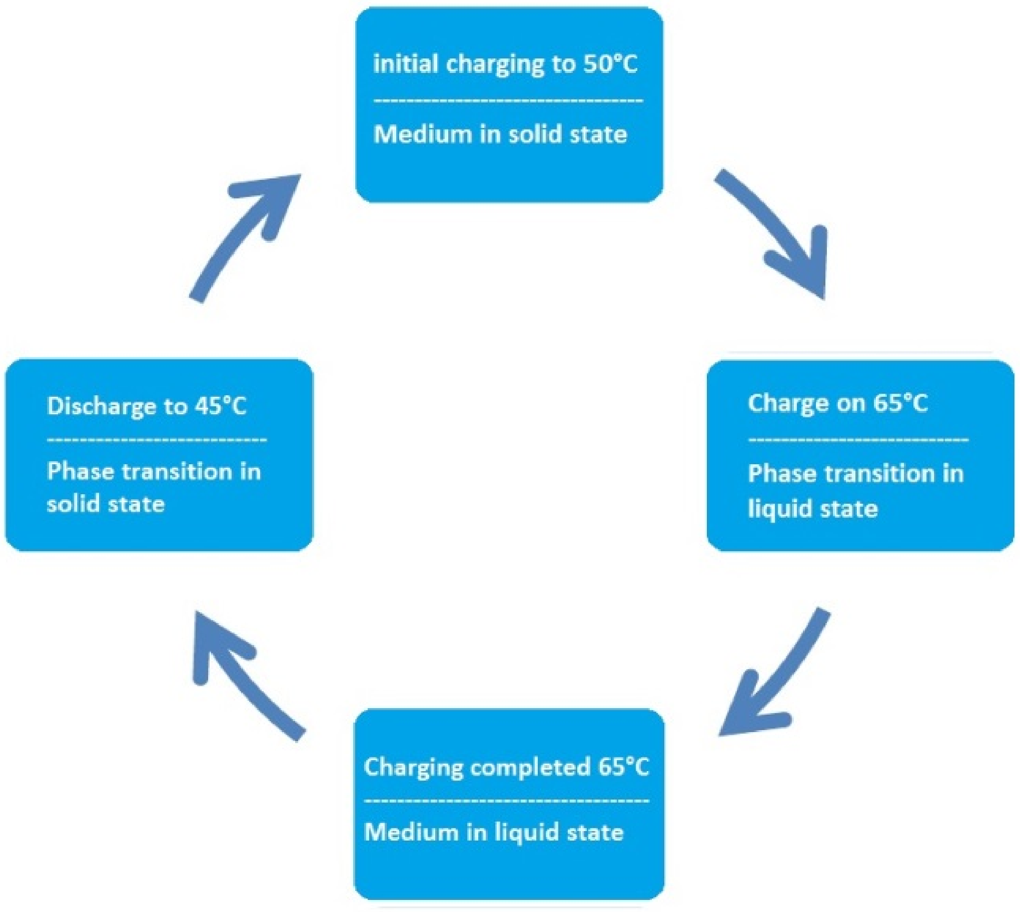


Fig. 4: Principle of operation [2]

As a representative of organic latent heat storage the prototype of a paraffin-tank was applied in which the paraffin type RT42 as a heat storage medium was used. The advantage of this medium is also in the use of latent heat during the phase change solid-liquid or liquid-solid.

Fig. 5: Buffer, salt-hydrate tank, paraffin tank

Also this medium has a higher thermal capacity per unit mass than water. The phase transition in this medium is in the temperature range of 35-50°C. Due to the use of phase change the PCM includes a storage capacity which is many times higher than conventional known materials. This can be seen in the chart below. [3]

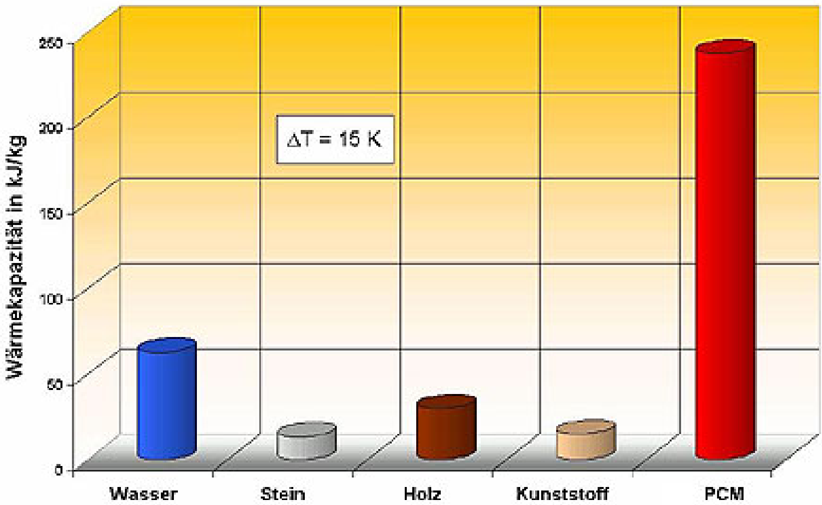


Fig. 6: Comparison of the heat capacity of different materials [3]

3. RESULTS

The first series of measurements includes the electrical energy consumption of the heat pump and the temperature rise in the buffer. From these results the thermal energy storage and the resulting performance of the heat pump have been calculated under the given boundary conditions. The interpretation of these results is discussed in the thesis: "Illustration of heat pump systems and possibilities for heat storage." [1]

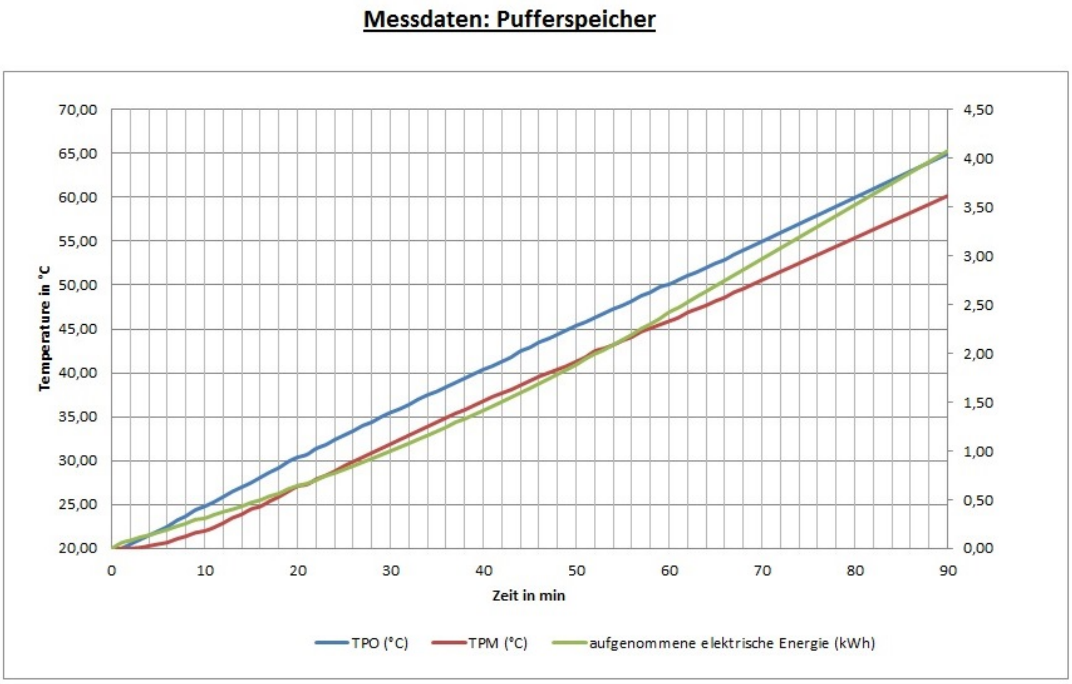


Fig. 7: Measurement data buffer

The next series of measurements was taken at the charge and discharge of the salt-hydrate tank by the buffer. The energy in the buffer has been provided by the heat pump, therefore the fluctuations in the flow temperature result.

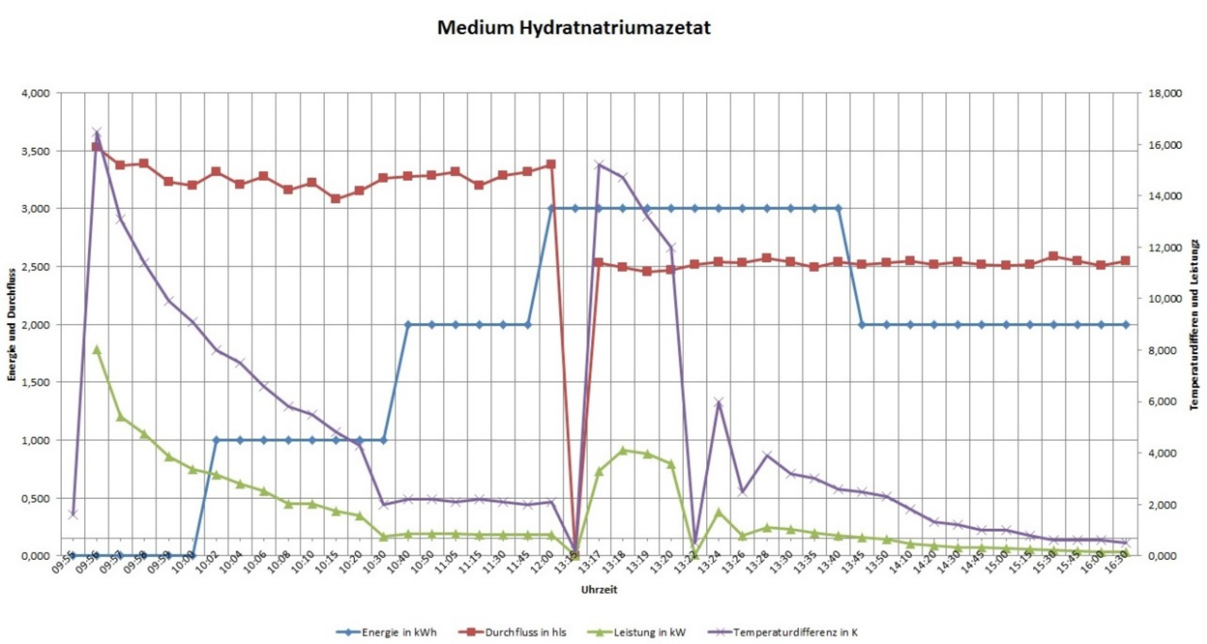


Fig. 8: Measurement data salt-hydrate tank

In this diagram it is seen that the storage of the measured salt-hydrate tank is 3 kWh. However, the whole energy could not be used.

To explore this phenomenon in more detail the same experiment was done with a paraffin tank which permits observation of the phase transition. For this, the energy from the buffer was passed directly into the paraffin tank. The results are shown in the following diagram.

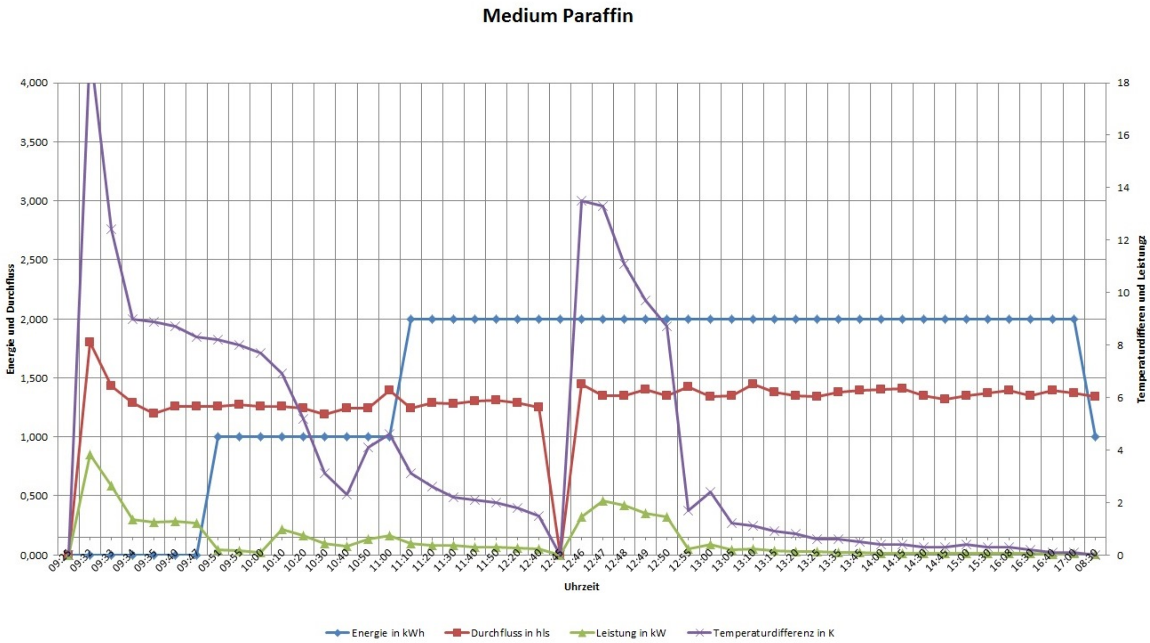


Fig. 8: Measurement data paraffin tank

The storage capacity of the measured paraffin tank was 2.0 kWh. As a cause of the faltering energy extraction following phenomenon could be detected.

With a too rapid energy removing or at too high temperature difference of storage medium and heat exchanger the phase transition starts in the extraction region, creating an insulating layer around the heat exchanger as shown in the following figure.

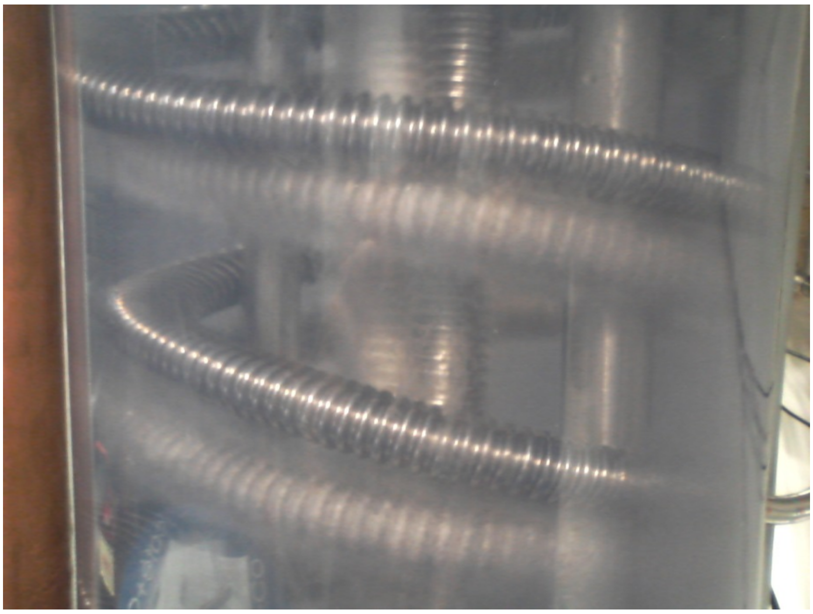


Fig. 9: Discharge of paraffin tank

This layer prevents further heat exchange and is only resolved by adjusting the energy removing and a balance in the media which leads to a return to the liquid state. From this observation it can be said that a constant withdrawal of energy from the latent heat storage is only possible in a moderate temperature range around the phase transition area.

4. CONCLUSION

Advanced latent heat storage materials of saline or paraffin base are produced for various applications and are available for nearly all temperature ranges. The needed temperature range depends on the type of heat generation as well as the employed heat dissipation system. Very important is that the return temperature is not significantly below the phase transition temperature. Otherwise it results in the formation of an insulating layer because of the storage medium solidification at the heat exchanger.

This effect can be avoided by the use of a traditional buffer or by a corresponding return temperature rising.

Ideally, the latent storage should be used for heat storage near the phase transition temperature range. This solution can take all advantages of the latent heat storage and the problems of high temperature differences can be compensated via the buffer. To this must be a corresponding volume of water temperature stabilized (stratification in the buffer) will be considered and carried out the connection of the latent storage only from this level. For the operation of the heat pump, this means an extension of the heating phase by expanding the storage volume and a much longer discharge cycle of the tank that comes into existence by the energy storage expansion because of the phase transition and requires an adjustment of the control concept.

5. REFERENCES

[1] Veranschaulichung von Wärmepumpensystemen und Möglichkeiten zur Wärmespeicherung, Peter Alois Morgenbesser, Fachhochschule Kärnten, 2013

[2] Datenblatt Wärmebatterie PCMX, Stand 26.06.2013

[3] www.rubitherm.de, 17.02.2014

AUTHORS ADDRESS

Stephan Thaler, MSc

Carinthia University of Applied Sciences

Europastrasse 4, A–9524 Villach, Austria

Tel: + 43 (0) 5 / 90500-2118

Email: *thaler@cuas.at*