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MOBILE THERMAL ENERGY STORAGE (M-TES)

Abstract: *The main world trends aimed at creating new energy systems, highly efficient and, at the same time, with a careful attitude to the surrounding environment, intensified the creation and protection of energy storage systems. One of the areas that is actively developing is mobile heat accumulators that work on this technology of latent heat storage.*

The article presents a new design of a mobile heat accumulator with a short-term heat storage period. A combination of several types of coolants is used as an accumulation system. The technical and technological characteristics of M-TES-0.5 MW are given. The most promising mobile thermal energy storage devices, which implement a similar principle of thermal energy conservation and have a positive experience of use, were noted.

Keywords: *thermal energy storage, mobile thermal energy storage, phase change material.*

Introduction

In countries with developed economy, there is a transition to smart energy consumption that is accompanied by the development of technologies with a careful attitude to natural resources and the surrounding environment. Energy-efficient technologies are being used, new equipment, automation and measuring equipment are being created. They reduce the cost of electrical and thermal energy. The main changes concern (Wirtza et al., 2020; Thermal networks, 2008; Union European. EU Energy in figures: Statistical pocketbook, 2020; Lunda et al., 2017; Lunda et al., 2014) with:

- lowering the heat carrier temperature;
- reduction of heat losses at each stage of heat supply;
- attraction of new non-traditional energy sources;
- creation of decentralized heat supply.

One of the technological solutions used in almost each of these issues is the conservation and accumulation of heat. Nowadays heat storage technologies, special equipment and materials are actively developing (Zayeda et al., 2020; Levenberg et al., 1991; Demchenko et al., 2020). The paper is devoted to the development of mobile heat accumulators operating based on latent heat technology (Guo et al., 2014; Du et al., 2020).

Within the framework of the state order in the Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine design documentation for Mobile Thermal Energy Storage (hereinafter M-TES) for transporting heat from various energy sources has been developed. As a result of the work carried out, M-TES with a heat output of 0.5 MW was manufactured and tested.

The design of the M-TES has several of original and at the same time universal solutions presented as objects of patents for inventions:

- design of the battery tank (patent application a2019 11450, patent No. 126579 dated 02.11.2022);
- the composition of the heat storage material used in the storage tank to increase the storage effect (patent application a2021 07588);
- design of the M-TES system as a whole (patent application a2021 01559).

The main purpose of using M-TES is to ensure the collection and primary processing of initial information; create a unified reporting system on performance indicators; improve the quality (completeness, accuracy, reliability, timeliness, consistency) of information; reduce the processing time of information thermal processes, the safety of information and fire safety.

Purpose and objectives of the work

The purpose of this work is to present a new design and review the design features of mobile thermal energy storage that work on the technology of hidden heat storage.

In accordance with the set goal, the following tasks are formulated:

- presentation of a new design of M-TES with a short-term accumulation cycle;
- consider the existing designs of M-TES and determine promising directions for the development of this industry.

Mobile thermal energy storage

The mobile thermal energy storage is a reliable universal design housed in a standard 20-foot Dry Cube "20DC" container. The container structure is equipped with roller shutters made of AG77 profile, namely, a system for closing technological openings. To insulate the containers in the container, liquid ceramic latex thermal insulation is used.

The container is divided by a partition into two parts an accumulation zone and an individual heating point (IHP).

The accumulation zone consists of 8 heat accumulators (hereinafter referred to as the HA) installed in containers in 2 rows. In the first row 4 heat accumulators are connected in series with each other, in the second row 4 heat accumulators are connected in parallel (Fig. 1). Each HA is equipped with temperature and pressure sensors. Charging and discharging of HA is carried out with the help of IHP.

The operation of the IHP is carried out through the entrance gate of the container. The ITP is not supposed to have a permanent stay of personnel. For remote monitoring and control the MTE-S is equipped with a PRO-X multifunctional GSM controller (OKOTM, Ukraine), which is usually used for remote monitoring and management at stationary objects simultaneously performing a number of functions.

To ensure adequate operation of the equipment, the M-TES is equipped with a modern automatic control system. The purpose of the automation system is to provide control of the heat supply process with the help of M-TES, access to information about its verification. Therefore, the system must be able to perform the following tasks:

- simplification of data entry;
- providing a secure authentication protocol for logging into the system;
- prevention of user errors when entering data;
- ensuring secure storage of entered data;
- providing open online access and search tools for open data located in the public module and the possibility of downloading them;
- creating an open API for developers to provide secure access to open data and download it in different formats.

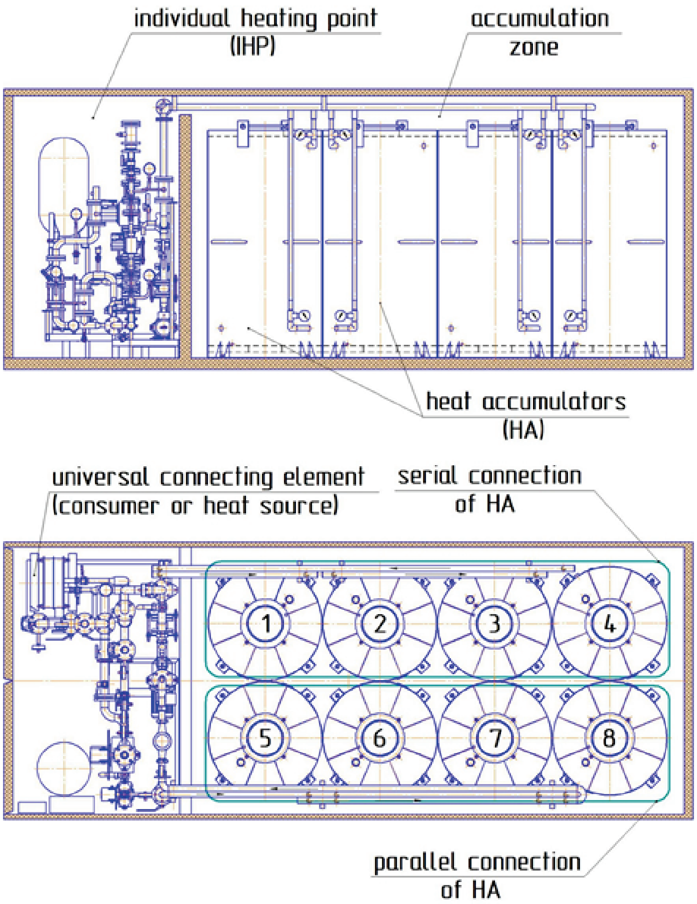

FIGURE 1. *Mobile thermal energy storage M-TES-0.5 MW*

To ensure the operation of M-TES the following are automated:

- temperature regulation of supply and return pipelines from the consumer and the storage module;
- management of M-TES charging and discharging processes;
- registration of unauthorized access and fire safety of M-TES;
- the geographical location of M-TES.

Technical characteristics of M-TES-0.5 MW

When creating M-TES-0.5 MW, a set of working design documentation was developed. Namely, there are Terms of Reference, Passport, Specifications, a set of working and design documentation. The main technical parameters of these documents are presented in Table 1.

TABLE 1. *Technical characteristics of M-TES-0.5 MW*

Parameter, unit of measurement	Value
Mode of operation of M-TES	cyclic
Thermal capacity of M-TES, MW, no more than	0.5
Pressure in tanks and pipelines of the accumulated compartment, MPa, no more than	0.07
Productivity of the heat carrier of the heating/cooling circuit, m^3/h, up to	2.5
Electric power installed, kW, no more than	8.2

table 1 continued

Parameter, unit of measurement	Value
The temperature of the heat carrier in the heat accumulator circuit when: – charging, °C – discharging, °C	 90 50
The temperature of the direct heat carrier during M-TES charging, °C The temperature of the return heat carrier during M-TES charging, °C	110 60
The temperature of the direct heat carrier during M-TES discharging, °C The temperature of the return heat carrier during M-TES discharging, °C	50 30
The volume of the heat carrier in the heat accumulator, m^3, up to	1.5
The volume of the heat carrier in M-TES as a whole, m^3, up to	12
Overall dimensions of M-TES, no more than – length, mm – width, mm – height, mm	 6300 3000 3000
Air temperature in the environment during operation, °C	-10….-15

The operation mode of M-TES can be intermittent, periodic or cyclical depending on the type of heat source, consumer conditions and the distance between them.

Overview of implemented projects based on mobile energy transportation

In the last 20 years, up to 100 projects using M-TES have been implemented in Europe, the USA, China and Japan. Let's consider the main aspects of some of them – Table 2.

Table 2. *Global experience of creating M-TES*

Heat productivity	PCM	Heat source	Consumer	Transportation distance	Developer	Construction of M-TES
200 kW/h	Acetate trihydrate	Any one with a temperature up to 115°C	–	–	Institute Fraunhofer UMSICHT	
2.3 MW/h	Zeolite (14 tons)	Steam from the incineration plant	To charge the storage of hot air 130°C and the drying process	7	Research center ZAE Bayern	
4 MW·h	Barium hydroxide (25 m^3, LSG Sky Chefs)	Used warm from a power plant)	Kitchen power plant	–	LSG Sky Chefs, Cologne	

table 2 continued

Heat productivity	PCM	Heat source	Consumer	Transportation distance	Developer	Construction of M-TES
–	–	Spent steam of the SANYO electronics factory	Pre-heating of the boiler reverse water	20	Osaka, Japan	
–	–	Heat collected from counters in Kiyose	City gymnasium	2.5		
–	–	Disposal of exhaust gases from the annealing furnace of the steel plant in Osaka	Public bath	3		
6.5 GJ	HECM-WD03 with the addition of rare earth elements	Waste heat of the steel plant in Dalyana	Neighboring hotels	–	Zhongyineng (Beijing) Technology Co, China	
–	–	Used steam of the power plant	Heating a neighboring school	–	Qingdao Aohuan New Energy Group Co., Ltd. , China	

First, heat transportation by road transport is economically feasible only if 3 factors are met:

- a small distance from the heat source to the consumer, usually within 50 km;
- availability of an available source of energy, for example, waste heat of enterprises, etc.;
- the temperature of the heat carrier is high enough to ensure the temperature range of M-TES operation.

Secondly, the determining limiting factor for the application of M-TES is the existing legal framework that regulates the safety of transportation and the economic basis for payment settlements.

Conclusions

As a result of the conducted research and experimental work, the following results were obtained:

1. A universal design of M-TES-0.5 MW has been developed, in comparison with existing M-TES, which has a number of original technical solutions aimed at obtaining the maximum possible coefficient of heat storage.
2. In the design of M-TES to increase heat transfer, the complex use of heat carriers – PCM, a water-based material with water-soluble polymers.
3. The optimal composition of a mixture of high-molecular solid saturated hydrocarbons and water-soluble polymers for intensifying the heat accumulation process was selected and laboratory researched, which made it possible to increase the specific heat capacity of TAM by 30% and expand the range of its use from -10°C to +120°C.
4. Approbation and field tests of the M-TES prototype with a thermal capacity of 0.5 MW proved that their implementation can fundamentally change the heat supply paradigm and in a short time introduce a 4th generation centralized heat supply system in Ukraine.

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