Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute for Thermal Energy Technology and Safety (ITES)

Karlsruhe Liquid Metal Laboratory (KALLA)

High-temperature Heat Storage System

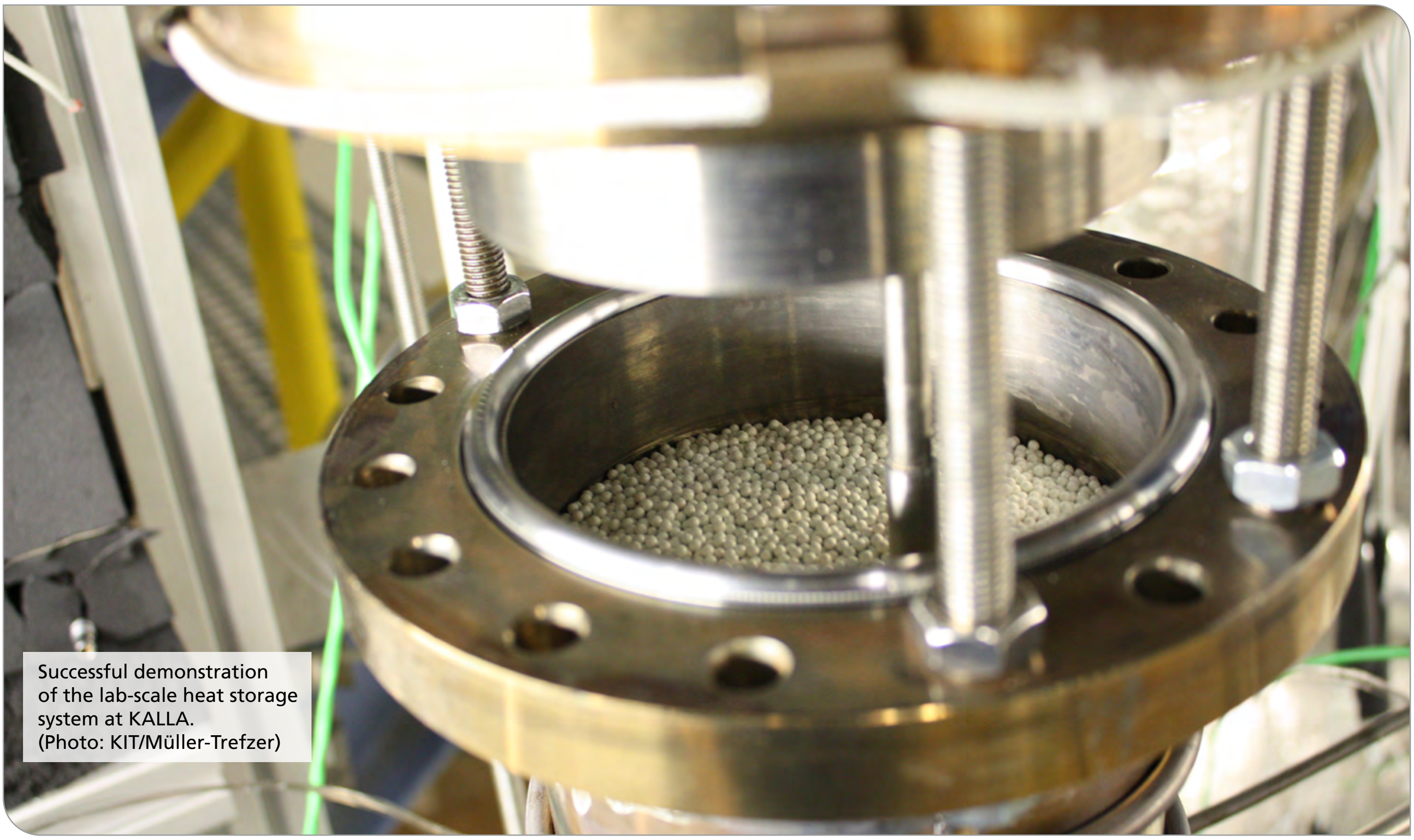
Liquid Metals as Heat Transfer Fluids in Ceramic Packed Beds

The energy transition makes industrial high-temperature processes face special challenges: How can the predominantly fossil energy consumed be replaced by emission-free sources? By electrification and a combination of renewable, but fluctuating energy sources with battery storage systems? By the transition to hydrogen that can be stored, but is very expensive as it is produced by electrolysis? Thermal energy or heat storage systems offer a comparably simple and inexpensive solution for storing energy in the form of heat as it is supplied or needed.

Heat storage systems are particularly advantageous when the energy already exists in thermal form, such as waste heat, or when energy is needed in thermal form as in case of industrial process heat. Direct conversion and storage of electricity in the form of heat at times when costs are low also is a favorable option for process heat, far better than electrochemical or chemical storage. As process heat makes up two thirds of the energy consumed by German industry and less than 10 percent are supplied from renewable sources, the CO_2 reduction potential is very high. Most of the process heat is required at temperatures above 500 °C, for which established heat storage solutions are not yet available on the market.

Heat Transfer by Liquid Metals

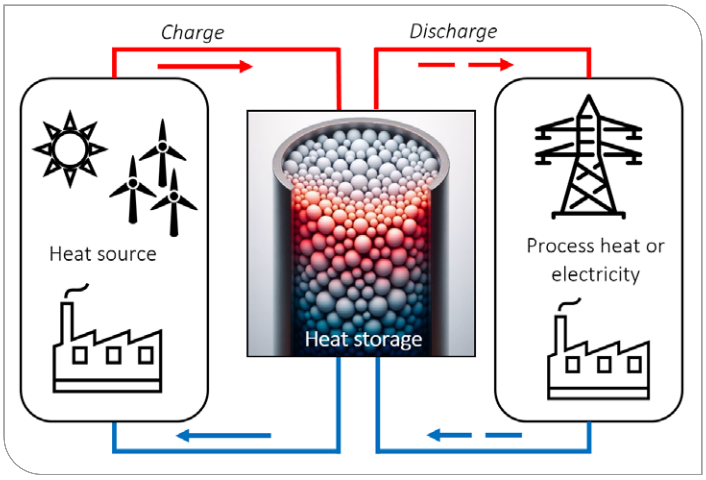
Heat transfer based on molten metal (so-called liquid metals) in heat storage systems is studied by the Karlsruhe Liquid Metal Laboratory (KALLA). Liquid metals allow for the storage of heat in a wide range and up to very high temperatures from about 100 °C to 1000 °C. The high thermal conductivity of liquid metals ensures heat transfer that is up to 100 times better than that of conventional liquids, such as oils, liquid salts, and gases. As a result, heat exchangers and heat storage systems can be designed in a much more compact way, which opens up innovative possibilities to efficiently introduce the stored high-temperature heat into processes or to recover it from them.



Successful demonstration of the lab-scale heat storage system at KALLA. (Photo: KIT/Müller-Trefzer)

Heat Storage in Ceramic Packed Beds

For heat storage, liquid metals are combined with ceramic beads of high storage density and long-term storage capacity. When storing heat, hot metal flows through the packed bed and releases heat to the ceramic material. Later on, heat can be removed by passing cooler liquid metal through the hot packed bed, which takes up the heat again. Then, the heated liquid metal transfers the heat to the process for which it is needed.



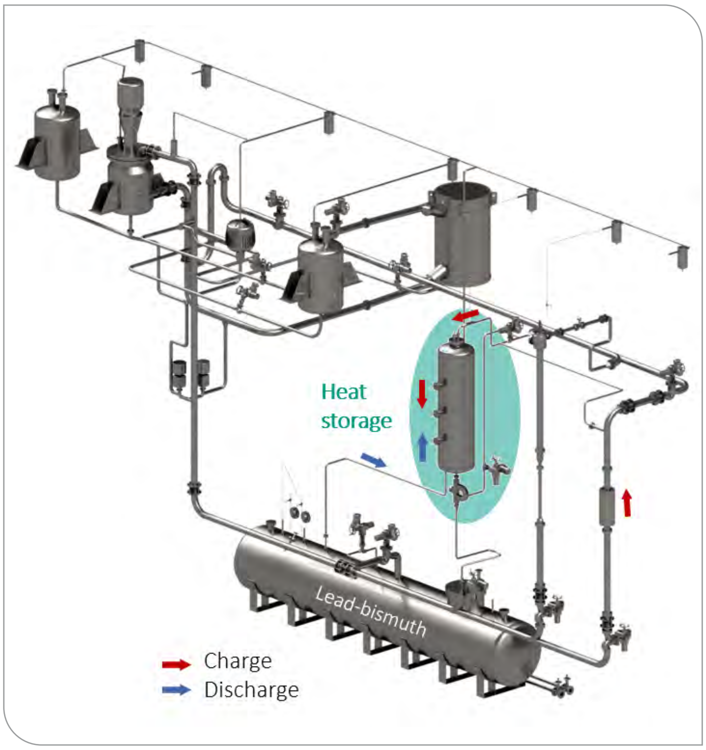
Use of a high-temperature heat storage system to supply process heat or electric power. (Graphics: KIT/KALLA)

Pilot Heat Storage at KALLA

Currently, a pilot experiment is being set up at the Karlsruhe Liquid Metal Laboratory to demonstrate the operation of a liquid metal-based heat storage system with a storage capacity of 100 kWh. For this, about 1.5 tonnes of ceramic filler material (zirconium silicate) are filled into a steel tank of 2 m height. Temperature sensors at more than 100 locations in the tank record the temperatures during charging and discharging and allow for the identification of ideal operation parameters. The liquid metal being used in this experiment is eutectic lead-bismuth, which has a melting point of about 125 °C.

High-temperature Tests of Materials and Components

In parallel, high-temperature materials and components are studied for operation at very high temperatures. Within the LIMELISA project funded by the Federal Ministry for Economic Affairs and Climate Action, a setup is being constructed, especially for tests of pumps and valves in liquid lead of up to 700 °C. The project is coordinated by KSB SE & Co. KGaA, a leading global manufacturer of pumps and valves. Further studies at KALLA investigate storage materials at high temperatures and look into alternative storage concepts.



Test of a pilot storage system in the lead-bismuth loop of KALLA. (Graphics: KIT/Daubner)

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