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Informationsdienst

# Zeolite/water refrigerators

- New freezer boxes maintain temperature for up to 30 hours
- Energy for the cooling process is stored loss-free
- Silent mini fridges in development
- Noiseless adsorption technology uses only environment-friendly refrigerants

Fig. 1

*These innovative mini fridges and cool boxes use less energy than conventional units.*

Researchers at Zeo-Tech GmbH in Unterschleissheim, Germany, have developed freezer boxes and mini refrigerators for mobile and stationary use that are designed to operate more efficiently in their respective application areas than current technology allows. As it is powered by heat, the adsorption-based cooling process can utilise a range of different energy sources.

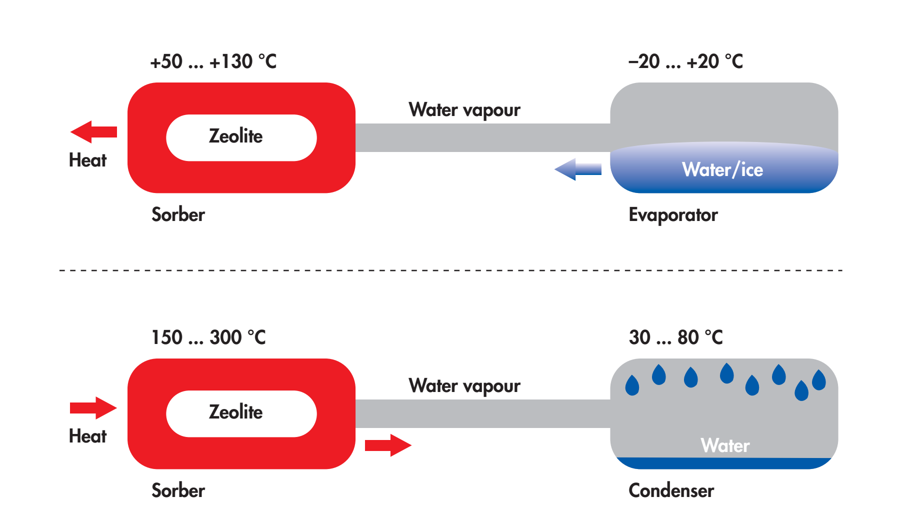
Mobile freezer boxes are already being tested in practice. Once they are charged via a normal power socket, they can be stored loss-free until used, when the cooling process is started at the touch of a button. After a short cooling time they reach deep freeze temperatures which are maintained over 24 hours. Active cooling means that contents are kept cold longer than in conventional boxes that use ice packs or phase change materials (PCMs). Compared to Peltier devices which enable continuous cooling, the advantage is greater energy efficiency and the fact that a power source is not required during the cooling phase. What's more, Peltier elements only allow a small reduction in temperature. Especially in summer this is frequently insufficient for many applications.

Based on the results from these portable boxes, the researchers extended the concept to continuous operation for stationary mini refrigerators. In their view, the main advantages are when silent operation is required or where heat is the only available power source. The absorption refrigerators that are currently used in the overwhelming majority of such cases have low energy efficiency and operate with ammonia and dichromate, both of which are harmful to health. In contrast, the new devices developed in the research project –which is supported by the German Federal Ministry of Economics and Technology – use environment-friendly and naturally occurring substances: zeolite and water. Compared to ammonia systems they are also at least 35% more energy efficient.

## ► How it works

The cooling process utilises the evaporative cooling of water combined with the ability of zeolites to adsorb large volumes of water vapour.
The water is located in the evaporator, which is an evacuated container. A second vessel containing zeolite is connected to the evaporator, with a valve in between. When the valve is opened, the adsorption of water vapour in the zeolite results in the continuous evaporation of more water. Meanwhile the evaporative cooling effect cools the remaining water to well below freezing. When the adsorptive capacity of the zeolite is exhausted, the process comes to a halt.
To regenerate the system, the zeolite is heated. The adsorbed water is expelled, and condenses in the evaporator.

Fig. 2: Cooling process and regeneration




## ► Transport box for chilled and frozen goods

Initially researchers implemented the functional principle in a transport box having a useful volume of 50 litres, which has now been developed to production-ready status. Insulated with 80 mm polyurethane foam, five walls of the Mobile Freezer are actively cooled by in-wall evaporators filled with one litre of water. A built-in cooler contains 13.5 kg of zeolite for the sorption process. Around half an hour after cooling commences, the inside temperature of the box reaches -18 °C. At an ambient temperature of 30 °C this can be maintained for around 24 hours (see Fig. 4). A 1,350 watt electrical heating element is provided for regeneration, which takes about two hours. Then the valve between the cooler and the evaporator is closed and the zeolite needs to be left to cool down for about five hours. Afterwards the cool box is ready for use again. It can be stored indefinitely before being cooled down again when the valve is opened.

### Testing the box in practice

Several identical systems, each optimised for the respective application, are being tested in practice by selected users. The aim is to demonstrate their practical suitability under various ambient conditions in comparison to systems that are currently available on the market. Hopefully this will enable the most promising products in terms of profitability and efficiency to be identified now, during the development phase. These models will then be prioritised for taking to the production stage. From past experience, dozens of different configurations will have to be tried out. The quantity, size and design of the devices will depend on the development results.

Fig. 3: Prototype 50 l transport box

Fig. 4: Cooling characteristics at 30 °C ambient temperature

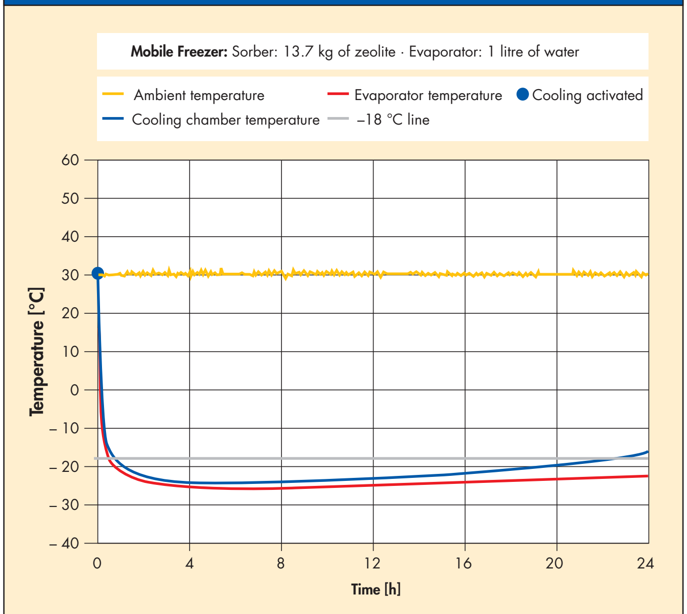



Fig. 5: Zeolite refrigeration systems for practical testing

## Conventional cool boxes and mini fridges

Three different refrigeration technologies are currently used for cool boxes and mini fridges. Each of them has its specific advantages and disadvantages.
Compressor refrigeration, which has become established for domestic appliances, has the lowest energy consumption. However, it is relatively expensive for small units and is not silent. Suitability for mobile use is limited as vibrations can prevent the system from working properly. A battery for power supply is also required.

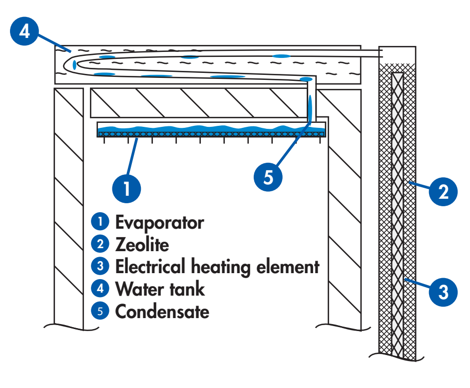
Thermoelectric Peltier elements, on the other hand, are extremely resilient. Cheap to produce, several million units are manufactured every year for use mainly in simple cool boxes. However, the technology is less than 10% energy efficient and can only achieve a maximum temperature range of 25 K. Although thermoelectric cooling itself is silent, fans are normally required to dissipate the heat. Complex solutions with external heat pipe systems increase costs and frequently also consume more energy.

Ammonia-based absorption units are both silent and suitable for mobile applications. Powered by electricity or heat, these systems have been sold for more than 80 years without major modifications and are typically used in mobile homes or as minibars in hotel rooms, for example. Their energy efficiency is limited: fridges with a 40 l capacity consume approx. 0.9 kWh/24 h at 25 °C ambient temperature. The chemical agents they use – ammonia and ammonium dichromate – must not be released into the environment as they are poisonous and carcinogenic.

# ▶ Silent mini fridges

Following successful tests with the cool boxes, the same refrigeration principle was modified for continuous cooling (see Fig. 6). Like with the cool box, a heating element dries out the zeolite sorber during the desorption phase. First of all, the expelled water vapour transfers the condensation heat to a water tank, which slowly releases the heat to the atmosphere during the subsequent sorption process. The condensate flows out into the evaporator. In the evaporator, the condensate is spread over a large area to ensure optimum use of the evaporator surfaces during the cooling phase. To maintain a low temperature during desorption, the evaporator is located at the top inside the cooling chamber. Warmer air around the evaporator stays in this upper region. The air only cools down in the cooling phase, when it falls to the bottom of the cooling chamber.
At the end of the desorption phase, the internal zeolite temperature is at an optimum temperature of over 200 °C. The exterior temperature is only 100-120 °C. As a result, even without extensive insulation, heat losses are limited to approx. 10-15% of the input energy. The adsorption heat is released automatically, without requiring any control system, directly following the desorption. There is no need for active ventilation, e.g. with adjustable ventilation grilles or an external fan.

**Fig. 6: Diagram of a zeolite mini refrigerator**




## Dimensioning

A well-insulated mobile fridge with a 40 l capacity requires a continuous cooling capacity of around 8-9 W to ensure an internal temperature of 5-8 °C at 25 °C ambient temperature. If the fridge is designed for a 24-hour cycle time, approximately 690 kJ of cooling energy needs to be generated per cycle. This is equivalent to the evaporation of approx. 300 g of water and requires a mass of zeolite of approx. 2 kg for the water adsorption.
The sorber contents are baked out once every 24 hours. Including thermal losses, this requires about 600 Wh of energy. The same size ammonia fridge, at best, would use 800 Wh in 24 hours, or at least 32% more. At higher ambient temperatures or if the ventilation around the fridge is poor, the zeolite system does even better as its energy consumption rises much less than that of the ammonia system.
The condensation heat is about 700 kJ. This can be absorbed by a water-filled heat buffer, for example, the design of which was optimised during the project. With a water buffer volume of 9 l, the water is heated by approx. 19 K as a result of the condensation. This water volume can be greatly reduced if suitable PCMs are used: these absorb a large quantity of heat when they melt and release it again when they solidify. To further minimise the weight of the mobile systems, units with optimised air heat exchangers were developed during the project. These release the condensation heat to the atmosphere by convection. Values in the comparison tests were calculated with these devices.
By converting commercially available cool boxes designed for normal temperature ranges it was possible to compare both electric and gas-powered systems with absorber refrigeration units, which are the most common type (see Fig. 7). Energy consumption when operated on electricity or gas was as much as 50% lower. At the same time the cooling performance was improved at ambient temperatures above 25 °C. ■

**Fig. 7: Cool box with 33 litre capacity: temperatures and energy consumption**

| | Zeolite refrigerator | | | | | | Ammonia absorber refrigerator | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Electric (230 V) | | Gas-powered | | Gas-powered combined with 12 V fan | | Electric (230 V) | | Gas-powered | |
| Ambient temperature | Internal temperature [°C], energy consumption [kWh/24 h] | | Internal temperature, energy consumption [kWh/24 h] / [g gas/24 h] | | Internal temperature, energy consumption [kWh/24 h] / [g gas/24 h] | | Internal temperature, energy consumption [kWh/24 h] | | Internal temperature, energy consumption [kWh/24 h] / [g gas/24 h] | |
| 25 °C | 5 °C | 0.75 | 5 °C | 1.11 / 86 | 5 °C | 1.05 / 81,4 | 5 °C | 1.5 | 7 °C | 2.36 / 178 |
| 32 °C | 6 °C | 1.34 | 6 °C | 1.77 / 140 | 6 °C | 1.46 / 112,4 | 7 °C | 1.8 | 8 °C | 2.6 / 206 |
| 38 °C | 12 °C | 1.3 | 10 °C | 2.41 / 187 | 7 °C | 2.8 / 201 | 13 °C | 1.9 | 17 °C | 2.6 / 206 |

# ▶ Outlook

All applications which previously used the problematic ammonia/water absorption pair can now be realised with the environment-friendly, energy-saving substance pair zeolite and water. Zeolite refrigeration units can operate on electricity or any form of heat. Energy savings compared to the old systems range from 25-50%. In terms of marketability, these energy savings are offset by higher material prices. In addition, considerable investment in new equipment is required in the production plant. Initially this investment will not generate any new revenues as the new fridges are merely taking the place of other units on the market. The researchers are working on various lines of development in order to translate the research results into commercial products.
Electric and gas-powered combination fridge/freezers for mobile homes, caravans and boats have reached an advanced stage of development. It is now possible to build units with two temperature ranges, i.e. a freezer compartment as well as a normal fridge. With suitable geometries it is possible to feed the recondensed water back into the frozen evaporator. Recently developed vacuum valves allow continuous operation with just one zeolite adsorber.
In stationary applications, the technology is suitable for efficient and silent hotel fridges, for example. Specifically using lower-cost off-peak electricity could further reduce the running costs. At the same time, appropriate PCMs in the condenser and evaporator should reduce the costs of the refrigeration unit and ensure favourable operating conditions during adsorption and desorption.
Transporting pharma and biotech products usually requires good temperature stability. A new thermostat regulator will enable zeolite refrigeration technology to be used for temperature-sensitive chilled cargo.
Solar thermal freezing stations for cold packs are also undergoing successful trials at the moment. Conventional water-filled cold packs are frozen outside the vacuum system and made available for refrigerated transport. The stationary system is particularly suitable for southern climates and can also be built and operated in large units.
Cooperation agreements have now been signed with leading companies for a range of applications with the aim of using this environment-friendly technology in mass-produced products.

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## ▶ ERGÄNZENDE INFORMATIONEN

**Internet**
- www.zeo-tech.de

**Literature (in German)**


- Maier-Laxhuber, P.; Wörz, R.; Schmidt, R.: Energieeffiziente und geräuschlose Kühlgeräte mit Zeolith-Adsorptionstechnik für den mobilen und/oder stationären Einsatz. Abschlussbericht. Zeo-Tech GmbH, Unterschleißheim (Hrsg.) Juli 2010. 57 S., FKZ 0327434A


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- Figs. 1-6: Zeo-Tech GmbH

**Service**
- This Projektinfo brochure is also available as an online document at www.bine.info under Publications/Projektinfos. Additional information in German, such as other project addresses and links, can be found under “Service”.

## PROJECT ORGANISATION


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