Introduction of Zeolite Technology into refrigeration systems.

LIFE04 ENV/LU/000829

Layman’s Report

The project was supported by the European Union within the bounds of the LIFE Programme

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Summary

The ZEOLITE project (LIFE04 ENV/L/000829) has been implemented by Dometic S.a.r.l., Luxembourg between December 2003 and November 2006. The objective of the LIFE project was the development and the introduction of a new type of technology for the refrigeration systems based on the innovative zeolite/water principle. The advantage of this new and environmental friendly cooling system is the use of natural elements (no refrigeration gas required). Moreover, the new refrigerators offer an increased mobility due to their independency from the power grid. The goal behind the project was the development of alternative systems that are complementary to the actual refrigeration systems, such as the compressor system and carbon dioxide snow.

The ZEOLITE project has been co-financed by the LIFE Programme with a grant amounting to 510,942 EUR, representing 30% from the total budget of 1,712,682 EUR.

The new refrigeration system developed by Dometic generates cooling capacity by using two natural elements (instead of cooling gases): Zeolite and water. Zeolite is a mineral that has the property to adsorb water vapour while releasing heat at the same time. It represents an interesting element to store energy and to transform it in heating or cooling agents. Due to its capacity of working independently from the power source for a specific period of time, the new technology suits mostly for the transport of food and other perishables. It could also be used in the medical field (transport of vaccines etc). The energy stored in the zeolite elements is used to keep the desired temperature in the refrigerators during the transport time.

During the implementation of the project, Dometic has built several transport and medical containers using zeolite/water technology, demonstrating that the new system is environmentally friendly and technically viable. Due to an increased energy consumption, compared with the conventional refrigerators during the regeneration phased, the Zeolite systems are economically feasible under specific circumstances.
Project background

Dometic S.à.r.l. is specialised in the production and distribution of cooling equipment to be used in motor vehicles for food transport and refrigerators and freezers for medical, laboratory and pharmaceutical applications. For the development of the new technology in our field of activity, Dometic has closely collaborated with the ZEO-TECH GmbH, Germany.

The current refrigeration systems are mostly based on two technologies in order to produce cold air:

- **Compressor system**: using chemical products;
- **Carbon dioxide snow**: formed by rapid evaporation of liquid carbon dioxide

Both of them induce gases emissions, thus having a negative impact on the ozone layer and on the greenhouse effect.

The new zeolite/water adsorption technology developed under this project was aiming at demonstrating that it is possible to reduce the emissions of refrigerating gases and to increase energy efficiency in the refrigeration sector using zeolite minerals.

The project was based on the new and innovative zeolite/water technology. Its advantage is given by the zeolite granulates that are non-poisonous, non-inflammable, naturally available and therefore compatible with the environment. More than 40 natural and 140 synthetic zeolites are known. The most important property of the zeolite is its characteristic of reversible adsorption of water (please refer to page 10). Even after several thousands of adsorption/desorption cycles, the structural changes of the crystal are insignificant in the process parameters, such as the pressure and the temperature.

The zeolite technology has been developed by ZEO-TECH GmbH, a German company that has assisted Dometic during the project implementation. On the basis of an agreement concluded with ZEO-TECH GmbH, Dometic received the exclusive rights for all the zeolite/water patent implication concerning food and medical transport containers.

The adsorption technology, based on the working pair zeolite/water, is well suited for the heating and refrigeration processes and inherently provides storage of heating and cooling energy. Heat is the only necessary energy input, so that the energy supply of the refrigerators can be assured by many sources (gas, wood, electricity, solar collectors etc). Zeolite/water systems can provide food and beverage refrigeration, mobile or stationary air conditioning, domestic hot water and general domestic heating.
The **technology process** distinguishes two different phases:

1. **The adsorption phase**: during the refrigeration phase (or adsorption) the zeolite attracts water vapour and incorporates it in its crystal while releasing heat at the same time. The internal pressure drops and the remaining water cools down and freezes immediately. This allows us to use it for cooling purposes.

2. **The desorption phase (regeneration)**: during the regeneration phase (or desorption), we heat the zeolite, the water molecules inside the zeolite leave the crystal as vapour, and liquefy, bringing the system back to the starting point.

The sequence of adsorption/desorption processes is completely reversible and can be repeated indefinitely. The refrigerating process may be started and interrupted at any moment.

**Activities and Results**

The Zeolite project consisted in the realization of 5 new types of transport containers based on the environmentally friendly zeolite/water adsorption technology. During the project duration, 22 new refrigerators (prototypes) have been produced and tested. In particular, the new types of containers have been developed for the following activities of Dometic:

- Containers for transporting food;
- Refrigerators for the medical sector (mainly for vaccines);
- Refrigerators for chilling beverages.

The main activities of the project consisted in the realisation of new moulds for the new transport containers (which contained the zeolite system), as well as the prototype testing and the corresponding certification activities.

A new design was required for the realisation of the moulds and transport containers. These activities have been performed in cooperation with other European companies (HENGEO, GRADEL, KARL HUGO, SCHREINER FORMEN, BSV).
The zeolite system has been incorporated into the stainless steel housing of the containers. The assembling and welding activities have been supported by another European company, SBI (see pictures below).

Prototype testing
The zeolite prototypes have been tested and adapted accordingly in order to eliminate any drawback that could negatively influence their performance. The tests allowed checking the process (containers and zeolite system) and optimizing it in order to anticipate and avoid possible problems during the future industrialization phase.

The following tests have been performed:

- **The temperature tests:** to check the distribution of the temperature inside the container as well as the average time a certain temperature range can be maintained.
- **Vibration tests:** to check the stability of the new refrigerators.
- **Regeneration tests:** to define the time needed for the regeneration process.
- **Leakage tests:** to check potential leaks of the system that may affect the pressure inside the system (see pictures below);

The temperature hold over time (time period spent while remaining at a certain defined temperature range) depends upon the ambient temperature as well as on the system design. For our catering container project the hold over exceeds 24 hours at 32 °C ambient temperature. Mounted on castors for perfect mobility, the insulated body has been designed to limit temperature changes to protect fresh products during transportation and ensure there is no breakdown in the cold chain.
The new zeolite refrigerators include three base models: ZR 400, ZR 650, ZR 1000. The first one (ZR 400) is specifically adapted for catering activities (chilled meals) as it can transport pans directly on a special stainless steel support (optional); ZR 650 and ZR 1000 models are ideal for fresh food transport in larger quantities and can be used in combination with a stainless steel support for separation shelves (optional). During the cooling process the zeolite system does not need any energy from outside. However in order to circulate air inside the unit and thus to ensure a perfect temperature distribution inside the container there are small ventilators for which a battery is included as standard. Furthermore this battery ensures the thermostatic regulation of the unit. During the system’s recharging phase this battery is also automatically recharged. Once the Zeolite is not able to continue the cooling process (depending on the ambient temperature, the container and the zeolite system’s design), the system can be regenerated easily by plugging it into an electric or any other power source (heat, solar, etc). The refrigerator will then be ready for a new transport.

Certification
In order to prove that the systems are inline with the strict regulations concerning the technical, environmental and safety aspects, Dometic has proceeded with the acquisition of the following certifications: CE certification according to the low voltage directive 73 / 23 EEC, CE certification according to the electromagnetic directive 89 / 336 EEC, EMI certification, ATP Approval, EPI Approval.

Environmental and economic results
Compared to the commonly used refrigeration systems, the zeolite systems have specific environmental and economical benefits:

- Reversible characteristic of the water cooling process;
- Indefinite life duration => no waste is generated;
- Independence of the energy source for certain period (more than 12 hours even in hot ambient environments) => increased mobility;
- No need for repairing or changing the system, since the life duration of the zeolite is eternal and the process is completely natural instead of mechanical;
- Energy is required only during the regeneration phase; so it may be done at any time, i.e. during the night when energy is less expensive.
Environmental effect of the project

The most significant environmental impacts of the new zeolite systems are:

- **The reduced emission of refrigerating gases**: First of all it allows the production of a new CFC-free refrigeration system and completely eliminates the carbon dioxide (except for the electricity used during the regeneration phase\(^1\)). So, the emissions of gases having a greenhouse effect will strongly decrease. Compared to a compressor based refrigerator (RF 650) which has a global warming potential (GWP) of 173,9 - on the basis of R11 -, the new zeolite system ZR-650 has **no GWP** due to the fact that no gases are used as cooling agents. Therefore, the zeolite refrigerators are environmentally neutral and its components will not be responsible for global warming.

- **Energy efficiency**: refrigeration equipment consumes electricity and the production of this energy sends subsequent CO2 (carbon dioxide) emissions into the atmosphere. By the simple fact of consuming energy over its life cycle, a refrigeration unit indirectly contributes to an increased greenhouse effect that is leading to global warming and climate change. This represents more than 80% of the global impact of the emissions of a refrigeration unit. By regenerating the zeolite systems via the electricity grid outside the peak time (during the nights), the power consumption between day and night is better balanced and optimized. As a result, the collapsing risk of the energy network could be lowered. In this way, on the long run, the zeolite technology promoted by Dometic is in line with the objective of the European Union of achieving 20% energy efficiency by the year 2020 as well as with the objective of securing the electricity networks against blackouts.

Nevertheless, for the time being, the new zeolite systems have shown bigger energy consumption (kWh within 24 hours) compared with the conventional systems based on compressor. It should be stated that the zeolite technology is still at the beginning of its development. Following a rational way of technology development and implementation, Dometic has proven that the zeolite refrigerators are technically feasible. Further research efforts have to be undertaken to fine-tune the zeolite systems in order to improve their economical feasibility, which is currently given only under certain conditions. Dometic is continuing to improve the energy consumption for the zeolite refrigerators, and hopes to decrease it by at least 50% in order to bring it closer to the level of conventional devices.

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\(^1\) For this case, the new system can be connected to solar collectors, and so entirely solve the energy supply aspect and allowing this to be completely independent.
The Zeolite project developed was perfectly in line with the 6th Environment Action Programme of the European Community and more particularly with the actions to reduce the greenhouses gas emissions. It was also in line with the United Nations Framework Convention on Climate Changes concerning the global reduction of greenhouses gas emissions.

As a result, Dometic is strongly confident that the Zeolite technology represents a suitable alternative to current, greenhouse-gas-producing refrigeration systems.

Visibility of the project

In order to assure appropriate visibility of the Zeolite project, Dometic has printed several brochures (more than 7,000 exemplars) and posters to present the Zeolite system during the meetings with the professionals or during the participation to fairs and exhibitions. The brochures have been published in English, French, German, Spanish, Portuguese and Italian, in order to cover a wide and interested public and to ease the access to information.

The meetings with professionals of the transport, medical and logistic sectors had a positive impact of the adaptation of the zeolite systems to the market needs. Dometic has presented the concept of the new technology to potential clients/users and has received helpful feedback.

Two departments of Dometic have been involved in the dissemination programme, responsible for the catering transport containers (food and beverage) and for the vaccines containers (medical).
The Zeolite project has been presented in several international and specialised magazines, such as “Logistics Business Magasine”, “L'Hotellerie” or “Decideur Cuisine”. The articles described the new prototype and the zeolite benefits.

Information on the new refrigerators developed during the LIFE project may be accessed on the main website of Dometic (www.dometic.lu). The webpage as well as the printed information materials highlighted the environmental impact of the zeolite systems.

In order to present the new container systems to the public and the results of the Zeolite project, Dometic has attended several exhibitions in France, Germany, United Kingdom, Ireland, Spain and Belgium, such as:

- **SITL** – International Week of Transport and Logistics, Paris, March 2004,
- **INTERCOOL** - International Trade Exhibition for Frozen Foods, Ice Cream and Refrigerating Technology, Düsseldorf, September 2004,
- **EQUIPHOTEL** - exhibition for the Restaurant, Hotel, Cafes & Catering Industries, Paris, October 2004, and November 2006,
- **SIRHA** - International Hotel Catering and Food Trade Exhibition, Lyon, January 2005,
- **IFEX** - International Food, Drink & Hospitality Exhibition, Dublin, April 2005
- **HOREQ** - Hotel and Restaurants Equipment Show, Madrid, October 2005
- **INTERGASTRA** - exhibition for the gastronomy sector, Stuttgart, February 2006,
- **HORECATEL** - exhibition for the hotel and gastronomy sector, Marche-en-Famenne, March 2006,
- **SIREST** - exhibition for the hotel and gastronomy sector, Paris, March 2006,
- **HORECA** - Trade Fair on Equipment for Hotels, Restaurants, Cafes and Communities, Gent, November 2006.

After the presentation of the new refrigerators at the exhibitions, Dometic received positive feedback as well as questions / suggestions for optimizing / modifying the products.
**Transferability**

Dometic believes that the zeolite/water technology represents a better alternative to the conventional refrigerating systems, for the utilisation under specific conditions, such as for the transport of food or medical products. Currently, the zeolite refrigerators represent a niche technology and can be further developed and improved, especially in terms of energy efficiency in order to better compete with the compressor systems.

Taking into account the mobility offered, the Zeolite refrigerators have a high spreading potential all over the world and especially where the energy networks are not yet well developed. From a geographical point of view, the project has no limits. It could be easily used in all European countries as well as in the third world, mostly in the transport of medical products (for example foe on spot medical relief missions). Positive feedback concerning the potential for commercialization has been received from our potential clients and from the professionals of the sector.

The system contains less components (there is no mechanical part), minimizing in this way the risk of interruptions and break downs. Dometic expects, for the new device, a lifecycle of 20 years and more (10 years in case of the compressor system). The extended lifecycle will preserve natural resources and reduce the waste and the recycle need.

Examples of new activities of the refrigeration sector are:

- General medical transport: i.e. blood, organs;
- Military sector: actually, the army camps use refrigerators which do need power supply if they are going to be used. With the zeolite, they will have a refrigerator system where the energy may be stored; there is no immediate need of any power supply. The stored energy e.g. refrigerating is switched off when needed;
- Air-conditioning, etc;