Heating and Cooling Magnified

In a series of articles Metkel Yebiyo and Graeme Maidment of SIRACH will review individual heating and cooling technologies on a bi-monthly basis. We will describe the technology, principle of operation, its main applications, the challenges and opportunities in penetrating market and what's needed for that to happen. This month we will describe magnetic refrigeration for heating or cooling.

Basic working principles

In the 2015 United Nations Climate Change Conference, COP 21 in Paris, world leaders have been negotiating to limit the global warming to below 2°C by 2100. These talks are necessary to avoid serious climate catastrophes and reduce greenhouse gas emissions by increasing the use of zero carbon technologies such as magnetic refrigeration for heating or cooling. This is an emerging, innovative and potential low carbon technology. Due to the increased concern about global warming and an ever increasing energy consumption, the interest in magnetic refrigeration as a new heating or cooling technology competitive to conventional vapour compression has grown considerably over the last 15 years. The principle of magnetic refrigeration is based on a phenomenon known as magnetocaloric effect (MCE). This was discovered by Emil Warburg in 1881 and is related to the property of some exotic materials such as Gadolinium and Dysprosium that heat up when applying a magnetic field and cool down when the magnetic field is removed. This is illustrated in Figure 1 below. It can be seen from the figure that by operating the magnet in four steps, it is possible to extract or reject heat and produce heating or cooling. The energy ($E = m.Cp.\Delta T$) generated during each magnetocaloric cycle depends on the variation of temperature ΔT, the mass of material (m) and its specific heat capacity (Cp). This effect is maximal at a specific temperature called the Curie temperature of the material.

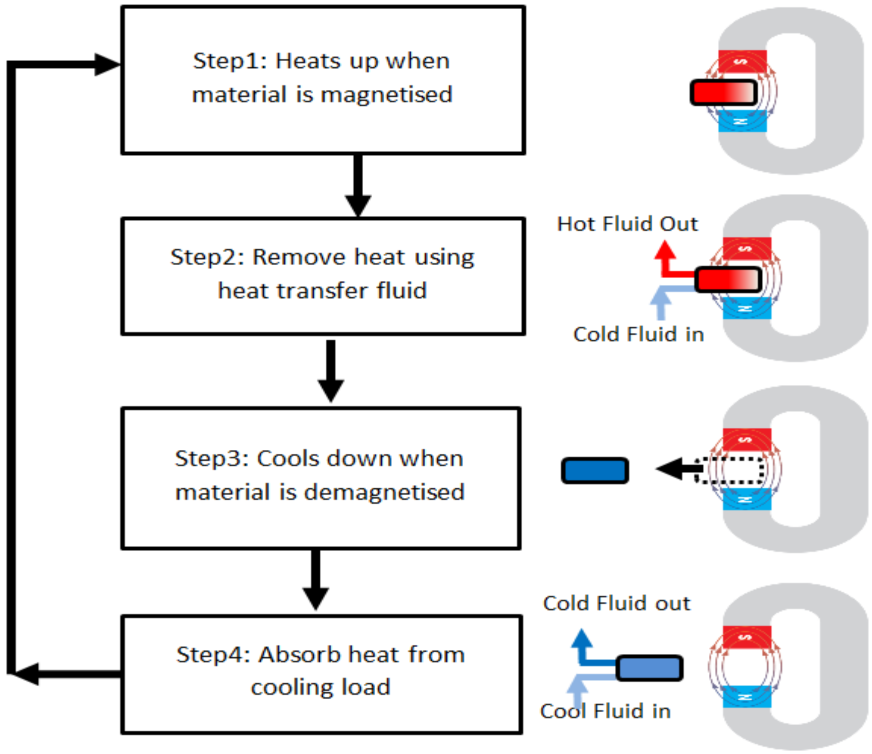

Figure 1 Schematic showing basic working principle of Magnetic Refrigeration

The main limitation of the magnetocaloric system shown in the figure is the relatively small temperature difference that can be achieved between the cold and hot source. A number of techniques have been used to increase this exchange such as Active Magnetic Regenerator Refrigeration (AMRR). The principle of this cycle uses a heat transfer fluid in contact with the magnetocaloric materials (MMC) flowing from the cold side to the hot side when the MMC is heated (magnetised) and from the hot side to the cold side when the MMC is cooled down (demagnetised). This progressively increases the temperature difference between the cold and hot source to about 20K making the system potentially suitable for commercial applications.

Potential Applications

There are various potential applications. First developments have been oriented to the commercial and domestic refrigeration markets for example display cases, beverage coolers, commercial or domestic fridges. However, magnetic cooling can also be completely adapted to other refrigeration applications such as air conditioning, including automotive, cryogenics or in heating applications (e.g heat pumps).

Benefits

The demand is likely to be driven by environmental regulations, since magnetic heating or cooling does not use a refrigerant but instead a heating or cooling fluid which could be water based. As such there are no leakage of refrigerant and no direct CO_2 emissions so it fully complies with all regulations such as F-gas in Europe or environmental protection EPA regulations in the US. In addition, the magnetocaloric cycle frequency being typically between 1 and 3 Hz, the rotation speed of the machine is slow and therefore very quiet compared to traditional compression systems. According to recent research it has been predicted that MCE will have a significantly higher efficiency (COP) than the present conventional methods, with a potential for a 30% energy saving.

Challenges

Even though some product commercialization has been completed, there still remain some challenges:

- The primary one is related to the supply of magnetocaloric materials, which are scarce. Therefore reducing material content or identification of new materials would benefit.
- Possibilities for reducing production costs. According to Cooltech Applications the fabrication process has not been optimized yet and costs are still high for allowing a large deployment scale.
- Interface optimisations (e.g Heat exchangers) between the devices and the equipment to be refrigerated have to be optimised for maximum efficiency.
- Development of prototypes for various specific applications.

Current market development

Although there is a lot of academic work by scientists & engineers from worldwide universities and research institutions the current market development is not fully mature. Some of the companies pushing the boundaries of this technology include, Cooltech Applications and NEXTPAC (working on heat pump applications), according to Cooltech Applications after 3 years industrializing and testing its magnetic refrigeration system, in 2015 they have now introduced a (150 – 700W) standard product specifically integrated within OEM's refrigerated equipment e.g. (Medica 2015), an image of their magnetic system is shown in Figure 2. By 2016 first tests will be carried out at end user's sites e.g. (supermarkets).

Figure 2 Image of magnetic system (image courtesy of Cooltech Applications)

Camfridge, currently involved in large EU research project on magnetic refrigeration http://elicit-project.eu/. In addition other multinationals from around the world who are working on similar technologies include such as Whirlpool, Electrolux, Astronautics, GE-Appliances, Samsung, Erasteel, Sanden, Chubu, BASF, VAC etc.

Verdict

Some potential savings in energy and no reliance on environmentally impacting refrigerant. Not ready yet but one to watch over the next 5 – 10 years.

To find out more about heating and cooling technology come to the regular SIRACH meetings held throughout the country at leading universities and businesses who engage in research. On the 20th April 2016 the SIRACH network event will visit The Centre for Sustainable Energy use in Food chains (CSEF). The Centre at Brunel University is dedicated to research into sustainable energy and carrying out cutting edge research investigating approaches and technologies that will have significant impacts in reducing CO_2 emissions, both in the short term, and the target of 80% reduction by 2050.

For more information or to be included on the SIRACH mailing list please register at www.sirach.org.uk or email info@sirach.org.uk