Institution: University of Nottingham

Unit of Assessment: 16

Title of case study: The Development of a Viable Low-Energy Alternative to Air Conditioning

1. Summary of the impact Research at the University of Nottingham into the use of phase-change materials as a means for heating and cooling buildings has resulted in the development of COOL-PHASE®, a product which is sold by Monodraught ltd. The system was launched in 2008 and has been installed in 136 buildings in the UK. COOL-PHASE® underpins the long-term growth strategy for the company and Monodraught has invested in employing 3 new staff and £250k in capital expenditure to make the unit suitable for mass production.

2. Underpinning research

Global warming has brought an increased dependence on air-conditioning and a growing demand for high-efficiency, lower-energy cooling systems. A simple way to satisfy these would be to incorporate concrete beams within a structure, exploiting the effect of night cooling to discharge heat stored in the thermal mass during the day. However, this solution is unsuitable for retrofit in existing buildings, which is where the greatest energy saving potential lies.

In the late 1990s, recognising the need for alternatives to conventional air conditioning, researchers at the University of Nottingham (UoN) began work to reduce energy consumption and avoid the use of refrigerant chemicals in potential systems. Dr David Etheridge (Associate Professor, University of Nottingham, 1997 - 2010) performed the original research on natural ventilation [2.1, 2.2] and led the team, with other key members including Visiting Professor David Reay (appointed honorary professor, University of Nottingham, 1994 - present) and Professor Saffa Riffat (Chair in Sustainable Energy, University of Nottingham, 1992 - present) to investigate the potential for combining natural ventilation with phase-change materials (PCM) within a retrofittable unit to increase the effective thermal mass of a building (EPSRC GR/R21639/01).

PCMs store energy in the form of latent heat and are more efficient than concrete, typically achieving the same heat storage with just four per cent of the mass. During the day heat is transferred to the PCM, “melting” it and reducing the temperature of the room; whilst at night heat is extracted from the PCM, “solidifying it”.

Researchers faced several challenges in the process of developing the system, which was supported through the use of a new theoretical model [2.3]. The initial idea was to use PCM in conjunction with heat pipes and a fan to make the system more effective. Heat pipes have the advantage of offering high heat transfer rates and are easy to maintain. The team also needed to find a way of making them reversible, meaning they would operate in a horizontal position.

Intelligent controls were designed to run this with minimal energy consumption. To allow for the expansion and contraction that occurs during the operating cycle, the system needed to be housed in a way that enabled heat transfer with the air in the room but without it coming into direct contact, which could result in air contamination. Lastly, the final product needed to be suitable for manufacturing at a cost that would rival or outperform conventional mass-produced air conditioning units [2.4].

Enthused by the potential of the technology, UoN liaised with industry to gain commercial expertise in product design and manufacture, as well as specialist input into how the research could be disseminated and marketed. Extensive research and testing resulted in the production of a demonstration system, using heat pipes embedded in a PCM with a fan to provide the necessary air movement.

Taking place from 2002 to 2004, a second stage of development refined the technology and developed two units for field trials. One was tested in the David Wilson Eco-House on the UoN campus and the other was tested externally. These trials demonstrated that the system could maintain a set temperature with the same effectiveness as an air conditioning unit [2.5]. Following

from this proof of fitness-for-purpose the team proceeded with their commercial exploitation plans.

3. References to the research

References (*Items marked with an asterisk indicate 3 most significant papers):*

2.1 Turnpenny, J.R., Etheridge, D.W. and Reay, D.A., 2000, Novel Ventilation Cooling System for Reducing Air Conditioning in Buildings, Part I: Testing and Theoretical Modelling, *Applied Thermal Engineering,* vol. 20, pp1019-1037 DOI: 10.1016/S1359-4311(99)00068-X

2.2 Turnpenny, J.R., Etheridge, D.W. and Reay, D.A., 2001, Novel Ventilation Cooling System for Reducing Air Conditioning in Buildings, Part II: Testing of Prototype, *Applied Thermal Engineering*, vol. 21, pp1203-1217 DOI: 10.1016/S1359-4311(01)00003-5

2.3 *Thaicham, P., Gadi, M. B. and Riffat, S. B., 2004, An investigation of microencapsulated phase change material slurry as a heat transfer fluid in a closed loop system, *Journal of the Energy Institute*, vol. 77 no. 513, pp. 108-115. Accession Number: WOS:000228272900005

2.4 *Etheridge, D.W., Murphy, K. and Reay, D., 2006, A PCM/Heat Pipe Cooling System for Reducing Air Conditioning in Buildings: Review of Options and Report on Field Tests, *Building Services Engineering Research and Technology*, vol. 27, no.1, pp27-39 DOI: 10.1191/0143624406bt142oa

2.5 *Khan, N., Su, Y., Hopper, N. and Riffat, S. B., 2011, Evaluation of Natural Ventilation and Cooling Systems using Dynamic Simulation Methods, *International Journal of Ventilation*, vol. 10, no.2 , pp.133-146. DOI: 10.5555/2044-4044-10.2.133, copy available on request.

Grants:

EPSRC: GR/R21639/01, Strategic Research For Sustainable Energy Technology In Buildings, 2001-2005 (£439k), (PI Riffat)

4. Details of the impact

UoN's innovative PCM alternative to conventional air conditioning has delivered a range of economic and environmental benefits since its successful commercialisation in 2008.

Backed by a patent application [4.1], the technology was licensed to Monodraught Ltd, resulting in the launch of COOL-PHASE® (Figure 1). Having already worked with UoN on the design and commercialisation of novel daylighting and ventilation products, Monodraught was keen to add a low-energy alternative to air conditioning to its range, and has since benefited from being the first company worldwide to build such a system; thus consolidating its position as a recognised market leader in low-carbon, low-energy products.

"The novel science and technologies underpinning the COOL-PHASE® cooling and ventilation system has elevated Monodraught's position in the industry as innovators" [4.2]

COOL-PHASE® was officially launched at the annual building industry exhibition, Interbuild, in October 2008. Although the industry is usually notoriously slow in its uptake of new technologies, even without the added pressure of an economic downturn, the system has enjoyed growth in sales each year since commercialisation. The original COOL-PHASE® was successfully installed at a total of 22 different commercial locations, including schools, colleges and retail outlets throughout the UK; with an average of six building installations at each location.

Further developments were undertaken by Monodraught in 2010 and 2011 to redesign Cool-Phase, from its original wall-mounted system into one which is now ceiling mounted. Sales of COOL-PHASE® are 11 units in 2011, 55 in 2012 and 48 up to June 2013; sales for 2013 are projected to total 150 by the end of the calendar year. COOL-PHASE® underpins the major growth strategy for the company, and the company's investment in appointing a Business Development Manager to solely focus on expanding the sales substantially over the coming years is evidence of the strategic importance of the product. Another part of the business case for COOL-PHASE® is exemplified by the investment of £250k over the past two years to make the unit suitable for mass production. Consequently, two additional production staff have been employed to achieve this - in total three new jobs have been created at Monodraught as a direct result of COOL-PHASE® [4.2].

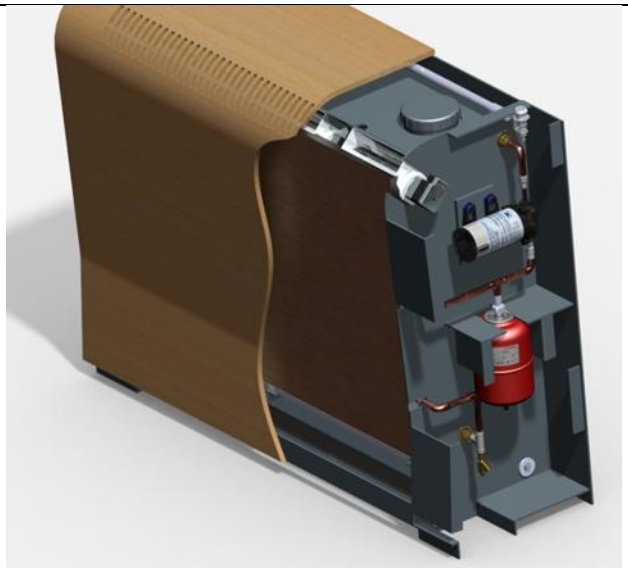

Figure 1: Graphic illustration of Cool-Phase system

Installations carried out between 2010 and 2011 include two serviced offices in central London for Workspace plc; a refurbished IT classroom at Scarborough Sixth-Form College; computer suites at the University of East London's Stratford Campus; and a 70m^2 school IT classroom, where the system was required to overcome high internal heat gains through IT equipment and glazing. Feedback has been extremely positive, with users comparing the cooling effect favourably with that of conventional air conditioning and noting that problems of discomfort associated with conventional systems have been overcome. Customers commented that they found the system to be "effective, sustainable and economically viable" and delivering "a marked improvement in terms of temperature" [4.3].

Figure 2: Two Cool-Phase units mounted on the ceiling of an ICT suite in the University of East London

Analysis of system performance in the 180m^2 ICT suite shown in Figure 2 was carried out by building simulation specialists. Results indicated that the installation of just two COOL-PHASE® units in place of conventional air conditioning would deliver financial savings of more than 26 per cent (approximately £10,000) and CO_2 savings of 12.8 tonnes over the anticipated system lifespan of 20 years [4.3].

COOL-PHASE® was also installed in a particular "problem" room in the Owen Building at Sheffield Hallam University - a 90-person teaching room on the tenth floor that consistently exhibited poor air quality and high temperatures. The room had no mechanical ventilation and was fitted with opening windows to one side; but due to the height of the building these were restricted to a 100mm maximum opening, limiting the effectiveness of natural ventilation. In November 2009 the University's Estates Department initiated environmental checks. The temperatures were consistently recorded at 25ºC at a time when November's outside temperatures were reaching only

5ºC. COOL-PHASE® was installed in March 2012 and Lee Allen, Building Services Engineer in the Sheffield Hallam University Estate Department said, "We monitored throughout the late March warm spell and recorded a room temperature peak of 23ºC when outside temperatures were hovering around 21ºC. We were very impressed with this performance compared to the 25ºC internal room temperatures we were experiencing in November". [4.4]

The contribution COOL-PHASE® has made to industry was recognised by the Chartered Institution of Building Services Engineers (CIBSE), which named the system 2012's Energy-Using Product of the Year [4.5]. CIBSE's awards are widely acknowledged as among the most prestigious in the industry and are presented at a high-profile ceremony traditionally attended by hundreds of the sector's leading figures. Recently, COOL-PHASE® won an IMPAX Ashden Award for Energy Innovation, which is a widely recognized sustainability award, due to its low energy requirements. The product consumes 90% less energy compared to alternatives on the market. Commenting for Ashden, the awards judging panel remarks: "This is a ground-breaking innovation from an established business that has built up a reputation for its long term commitment to sustainable buildings in the UK. It is no exaggeration to say this could potentially change the whole ventilation and cooling market." [4.6]

5. Sources to corroborate the impact

4.1 Patent: EP2131112, *Building Cooling Apparatus Using PCM for Loading the Reservoir During Night-Time*. Inventors: Hopper, N, Butters, M, Hooley, A, and Etheridge, D Publication date: Jan 20, 2010; Filing date: Jun 4, 2008; Priority date: Jun 4, 2008
4.2 Statement from Nick Hopper, Technical Director, Monodraught. Available on file
4.3 Notre Dame School case study brochure, pdf available on file.
4.4 http://www.monodraught.com/news/6/monodraughts-cool-phase-system-is-specified-for-problem-room-at-sheffield-hallam-university/
4.5 http://www.cibseawards.org/2012-winners/
4.6 http://www.ashden.org/files/Monodraught2013winner.pdf