FINAL TECHNICAL REPORT

CONTRACT No.:	ENK6-CT-2000-00346
PROJECT No.:	NNE5-2000-00511
ACRONYM:	EVAPCOOL

TITLE: Passive Downdraught Cooling Systems Using Porous Ceramic Evaporators**.**

PROJECT CO-ORDINATOR:	WSP ENVIRONMENTAL LTD
PARTNERS:	UNIVERSITY OF NOTTINGHAM, UK
	AXIMA LAB., SWITZERLAND

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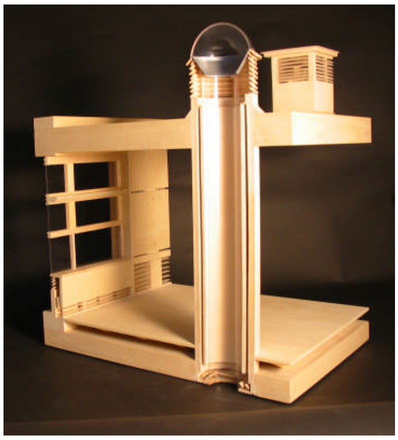
PART 1 - PUBLISHABLE REPORT

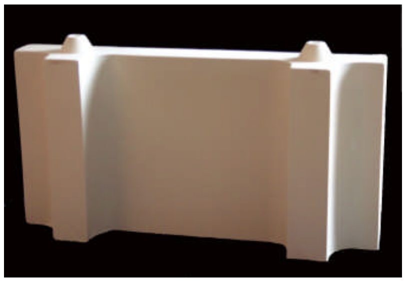
1.1 Executive Publishable Summary

The Evapcool project was initiated to design, develop and test new porous ceramic products for improved evaporator performance as part of an innovative cooling system and for integration within buildings. The main parameters affecting the rate of evaporation are ambient conditions (dry - wet bulb air temperature) and the rate of air movement over the evaporating surface, as well as water pressure and porosity of the evaporator. Theoretical models of both the direct and indirect evaporative cooling systems were found to have reasonable agreement with the climate chamber at Nottingham University. The casting technique was used in this project for the manufacture of the prototype evaporators, which were designed to be stacked, hung or cantilevered, according to the different options for building integration. The components developed in the project are the subject of a patent application, and commercial partners are being sought to make these components available in the market.



1. Physical Model of Office Integration

A design proposal for the integration of theses components within an office building in Teheran, Iran, was tested using dynamic thermal analysis (Trnsys) and CFD. Results indicated that for this location, the Evapcool system will meet 85% of the cooling load of the offices. Predicted annual energy savings for cooling were 32-42kWh/m2. The analysis for this project also revealed the degradation in performance with height of the array. From this data a simplified design tool has been developed to enable designers to size the system. A series of seminars and workshops devoted to downdraught cooling are planned to disseminate this research project.

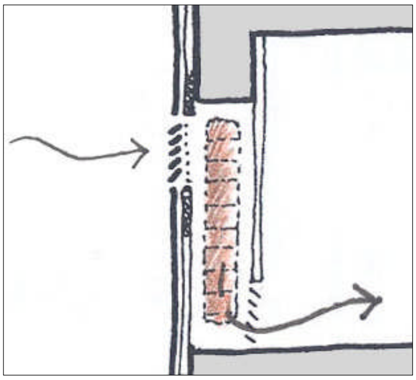


2. Stacked Evaporator Prototype

3. Hung Prototype

1.2 Publishable Synthesis Report

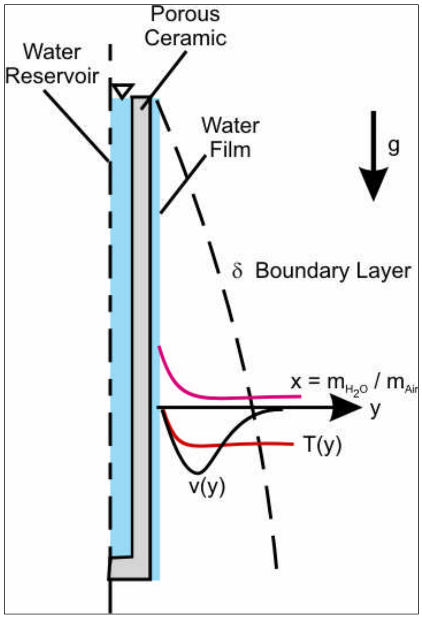
The Evapcool research project is concerned with the application of direct and indirect evaporative cooling in non domestic buildings. Evapcool was preceded by the Joule research project into Passive Downdraught Evaporative Cooling (PDEC - Contract No. JOR3-CT95-0078, 1996-1999). PDEC has been found to be technically and economically viable for non-domestic buildings. A number of buildings (including the recent Malta Stock Exchange [1]) have successfully applied the system. However, most PDEC applications use misting nozzles under high pressure to generate a high rate of evaporation and this has a number of disadvantages which tend to preclude its use for small non-domestic projects or residential buildings.



4. Principle of operation of the direct system

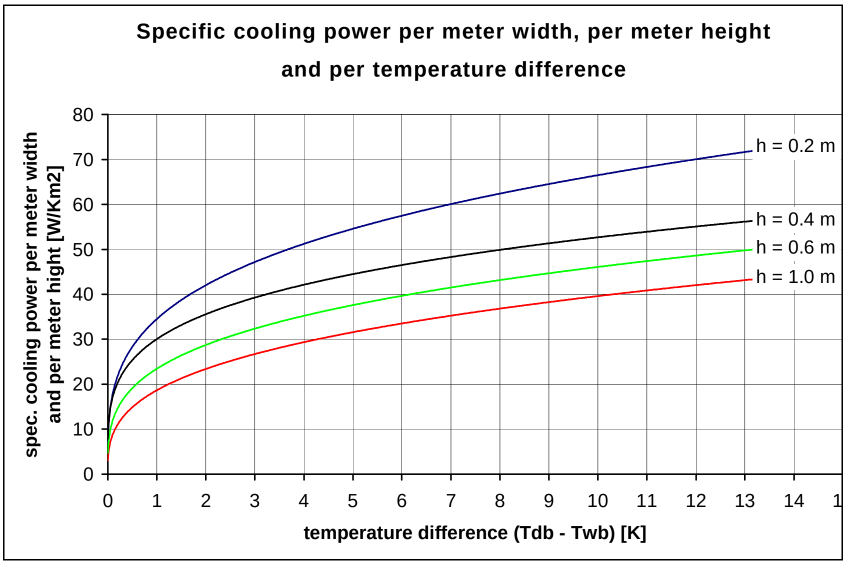
In reviewing traditional evaporative cooling techniques using porous ceramics, opportunities for improving the performance of this very simple technique became apparent and formed the basis of a patent application related to both direct and indirect evaporative cooling systems (UK Patent Application No. 0325891.0). It also became apparent that little analysis had been undertaken of the process of evaporative cooling through porous ceramic. The Evapcool Project was thus initiated in order to develop theoretical models of this process and to design, develop and test new products for improved evaporator performance and for their integration within buildings.

<u>Theoretical Models</u> – The rate of evaporation (and thus cooling) of a porous ceramic evaporator (PCE) depends on the ambient conditions (dry and wet bulb air temperature) and the rate of air movement over the surface, as well as the water pressure and the porosity of the PCE. The use of both CFD and dynamic thermal modelling contributed to the theoretical analysis and the creation of a simplified steady state calculation tool to enable designers to calculate the performance of different direct system configurations. A model was also developed of the indirect system but cooling performance for the indirect system was found to be 0.2-0.5 of the performance of the direct system and therefore the indirect system was not developed beyond the laboratory scale prototype.

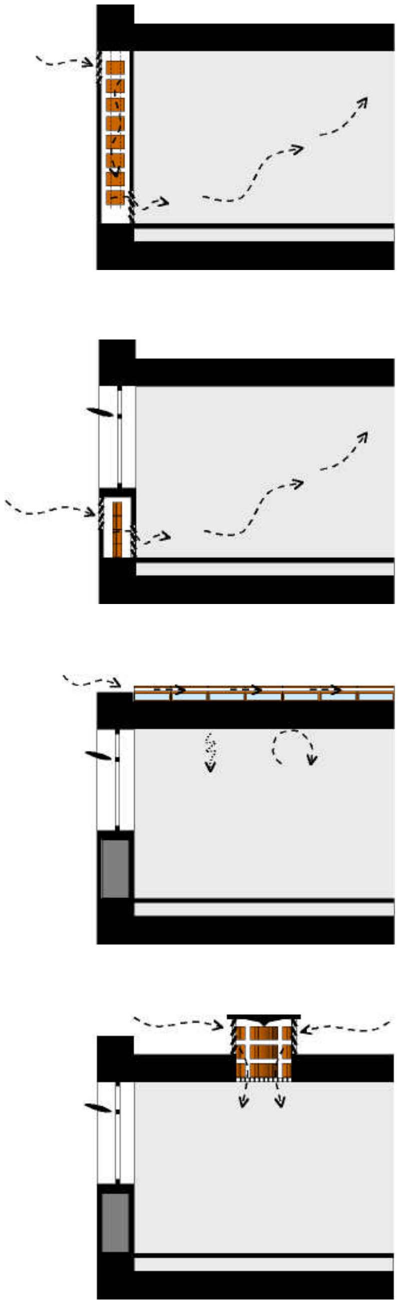


5. Assumptions of Theoretical Models

Prototype Design and Testing – Most ceramic building products (e.g. cladding panels) are produced by extrusion. By contrast, many domestic ceramic products (e.g. pots, jars, etc.) are produced by casting. The casting technique allows the creation of a container for water, but there are limitations imposed by this production technique on the size and shape of the container. Both the opportunities and limitations of the casting technique were explored in the process of designing a number of different ceramic components for the new direct and indirect evaporative cooling systems. Laboratory testing revealed that better performance would generally be achieved by the direct system, and so full scale prototype assemblies of two of the different components designs were tested in a climate chamber at University of Nottingham. Both systems showed similar values of specific cooling when compared at similar air volume flow rates. The experimental work allowed the performance to be characterised in terms of cooling as a function of the difference between saturated vapour pressure (e_s) and vapour pressure of the supply air (e).

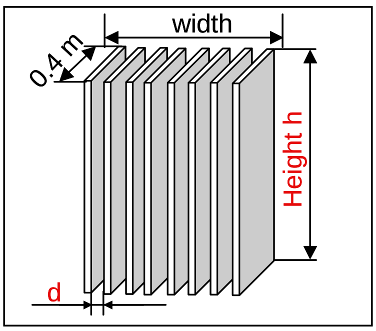


6. Specific cooling power per meter width, per meter height and per temperature difference.



7. Integration Options

System Design and Performance Analysis – Generic design solutions for the integration of the direct systems into wall and roof assemblies were developed to explore and illustrate the practical implications of application. These were illustrated through a series of generic drawings and model studies. The integration of these prototype systems into a small office building project in Teheran, Iran has also been proposed, and the overall system (i.e. building) performance has been assessed. Results from the analysis revealed that, for this case study in this location, the Evapcool

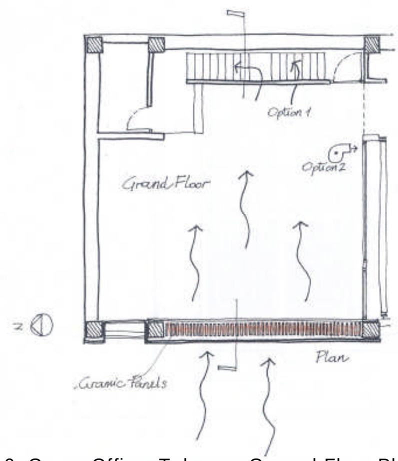


8. Direct System

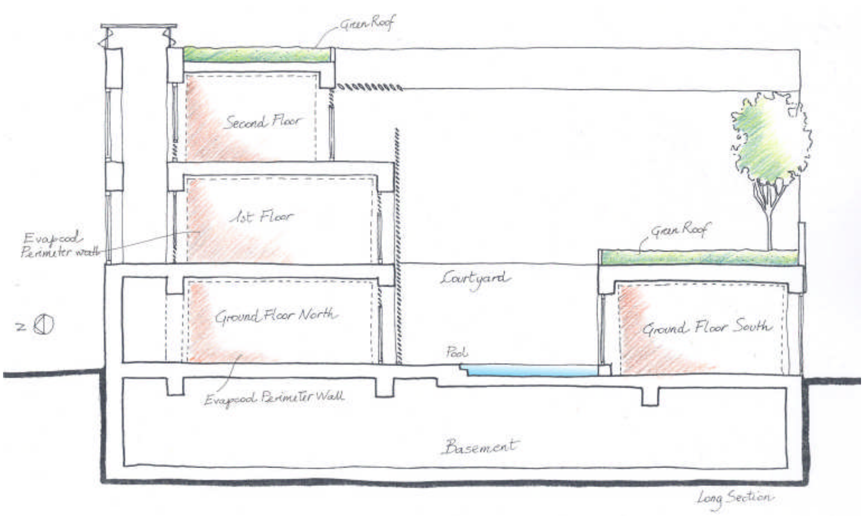
system will meet 85% of the cooling load of the office (i.e. a threshold temperature of 26degC will only be exceeded for 15% of the time). The predicted annual energy savings for cooling is 32-42 kWh/m2 (electricity based on a set point of 26degC), where the annual water consumption of the system was estimated at approximately 5liters per person per day.

The analysis also revealed the degradation in performance with height of the array. Greatest efficiency can be achieved if the height of the array can be limited to 0.2m. However, in practice, a greater height may be required in order to meet the cooling need. This data has been used in the definition of a performance nomogram to give designers the information required for preliminary sizing of a system.

9. ‘Hanging’ Prototype installed in Nottingham

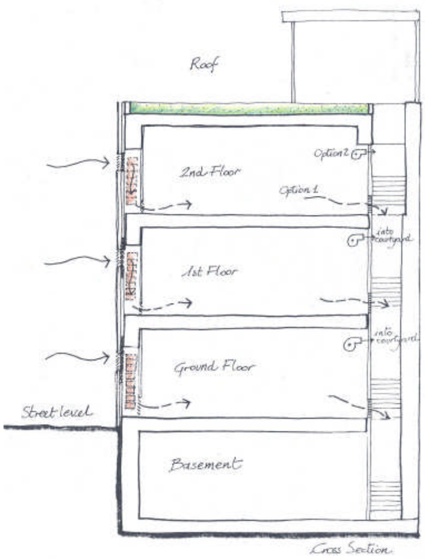


10. Green Office, Teheran, Ground Floor Plan



12. Proposed integration at the Green Office Building in Teheran

<u>Further developments and plans for exploitations</u> - The project has developed a number of components which are ‘close to market’. These components are the subject of a further patent application (UK Patent Application No. 0325891.0) and commercial partners are being sought in various parts of Europe and in Iran. The development by UK ceramic manufacturers of new material for use in the moulds required for casting, may lead to substantial reductions in production costs. Evapcool system costs will have to be lower than the costs of ‘comfort cooling’ in Europe (desert coolers in Iran) if it is to be taken up very widely. This is possible, but will require wider knowledge of the opportunities and benefits of the system to encourage take up and application on a wider scale.



11 Green Office, Teheran, Cross Section

A working demonstration project is vital. The project in Teheran is due for completion in 2004 and further support for this project will be sought from the EC under the COOPENER programme. The University of Nottingham and WSP Environmental are also actively seeking the opportunity to demonstrate Evapcool in South of Spain and Greece.

A short publication summarising the experience, opportunities and implications of Evapcool, PDEC and Hybrid Downdraught Cooling would act as an important catalyst to promote further uptake. The interest in Iran shown for the project is also indicative of opportunities in other developing countries with similar climate regions. The Evapcool Partners would like to hear from companies, institutions and individuals interested in the further development of these low energy cooling techniques. A series of seminars and workshops entirely devoted to Downdraught Cooling is planned.