Faculty of Engineering, Science and Technology

Division of Environmental, Energy and Building Services Engineering

Research Report 2002-2003

Research in the Division reflects long-standing tradition and an excellent established record along with the response of our staff to new national and international trends and needs. Research staff and students carry out high standard theoretical & fundamental research as well as investigations of practical relevance usually funded by government organizations and industry. State of the art research facilities are available in the National College Laboratories.

Our research areas include:

Refrigeration and Air-conditioning

Heat Transfer and Thermo fluid systems

Energy Studies

Environmental & Building Acoustics.

This brief document summarises current research projects in the Division.

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Contents

A fundamental investigation of the mechanism of the critical heat flux including the effect of an electric field

Post doctoral Researcher: vacant
Supervisory team: Prof. T. G. Karayiannis Dr K. Sefiane (Edinburgh Univ.) and Dr D. Kenning (Oxford Univ.)
Funding: EPSRC, £279K (South Bank £154K and Edinburgh £125)

The ability of engineers to predict and increase the magnitute of the critical heat flux (CHF) is of paramount importance in many technological applications. However, this requires correct understanding of the mechanism leading to CHF. Currently, there is considerable controversy amongst researchers on the controlling mechanism(s) and the various proposed models are not generally convincing or applicable. Past work has identified the role played by the trible line region and the contact line between solid, liquid and vapour and in modelling the CHF mechanism, the applicants propose that the controlling mechanism leading to the boiling crisis is due to instabilities occuring at the trible line. Instabilities responsible for such a mechanism originate from intense evaporation rates (recoil instability) and thermal variations (thermocapilary instability). In this theoretical and experimental investigation, the applicants will endeavour to model, develop and verify the new proposed mechanism for CHF, i.e. that it is caused by the recoil and thermocapilary instabilities. The use of a third, externally imposed and controlled instability caused by an electrostatic field across the fluid domain will be modelled. This will provide the methodology for predicting the electrohydrodynamic enhancement of the CHF, provide new data and assist in the verification of the proposed new mechanism for the boiling crisis. The modelling resullts will be compared with detailed and highly accurate experimental results.

The principal objectives of the proposed research are:

1. Explore the fundamentals of a new mechanism for boiling crisis - clarify importance of new mechanisms.

2. Include EHD and investigate the coupling/competition which may exist between thermocapilary and recoil instabilities and the electric force at the evaporating surface to help elucidate/verify proposed mechanisms, analysis and model.

3. Propose new modelling for EHD enhancement technique at the crtical heat flux.

4. Obtain new data for EHD enhanced critical heat flux.

Numerical study of moving boundary problems: application in arteries and coriolis mass flowmeters

Research Student: Xu Zhao
Supervisory team: Prof T.G. Karayiannis and Prof M.W. Collins
Funding: ORS Award, Micro Motion £10K in equipment.

A variety of physical phenomena involve the coupling of single and two-phase flow with boundaries that move, deform or evolve in time. They have been classified as Moving Boundary Problems (MBPs), in which the boundary domain is not known in advance and needs to be determined as part of the solution. This research applies advanced computing techniques in this multi-disciplinary area by creating a "general use" program. Four different commercial software (ANSYS, CFX4.4, CFX5.5 and BLOODSIM2.0) have been involved in this project. The aims of the PhD programme include: (i) The testing of existing code, BLOODSIM, for various application of MBPs, (ii) The establishment of the numerical methodology and the production of an iterative coupling program (ANSYS-CFX4.4) for general use in MBPs, (iii) The application of coupling approaches to blood flow in arteries as a means of validation and derivation of new results, (iv) the use of the coupled programs in the study of Coriolis Mass Flowmeters (CMFs) and the development of design parameters for the use of CMFs in single and two-phase flow.

The software development and integration work has now been completed. It comprises the application and evaluation of existing codes on various models, the creation of a dynamic mesh control technique, the completion of the data exchange format between different software, and the program control relating to relaxation, stability and convergence. Two different coupling approaches have been proposed, i.e. BLOODSIM2.0 and ANSYS-CFX4.4. They have been applied to water flow in linear elastic tubes and blood flow in linear and nonlinear elastic arteries (see Figure 1). Satisfactory results have been achieved so far. Single and two-phase flow in a straight CMF remains to be tested (see Figure 2).

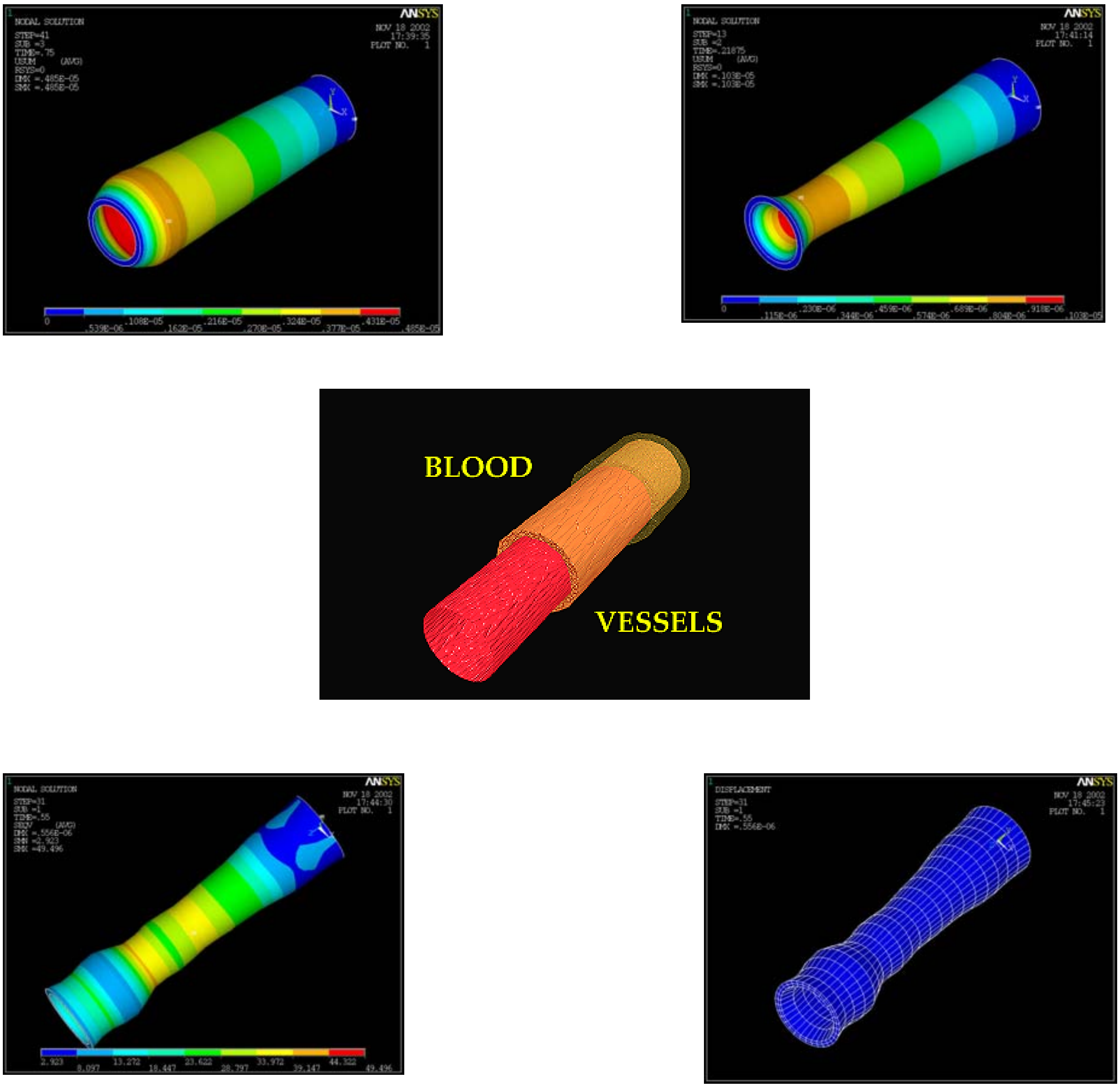


Figure 1 Blood flow in arteries

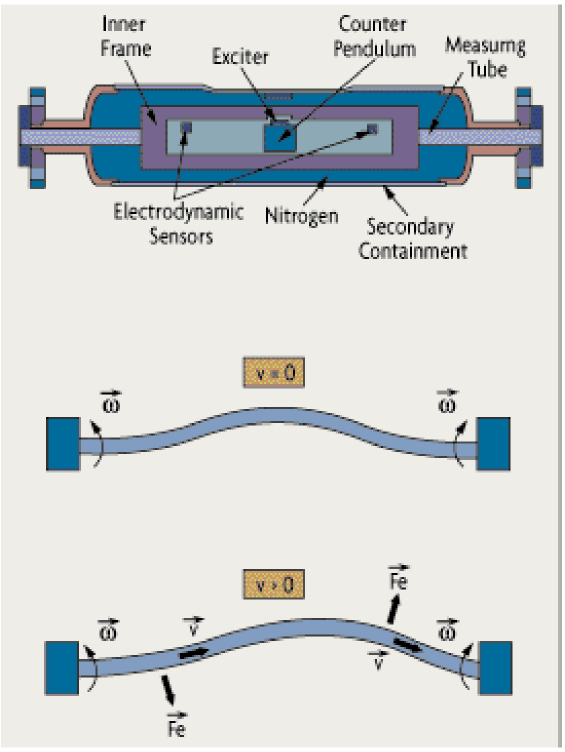
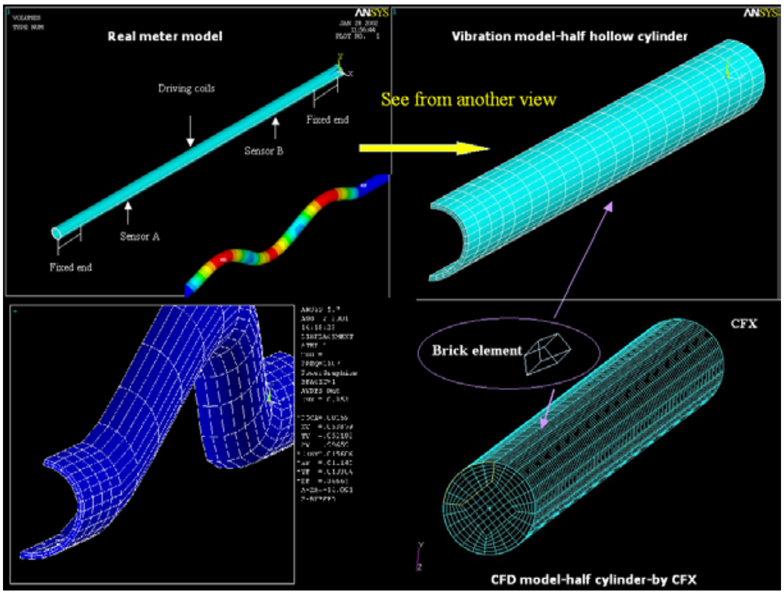
	
v Fluid streamwise velocity, F_e Coriolis force, ω rotational velocity Straight-shape coriolis mass flowmeters	Simulation model of coriois mass flow meter

Figure 2 Coriolis mass flowmeters

Flow boiling of R134a refrigerant-oil mixture

Researcher: I. Dabboussi
Supervisor: Prof.T.G. Karayiannis

The present project is concerned with flow boiling for R134a and oil mixtures. The purpose of this research is to present a comprehensive study for boiling in a horizontal tube and to investigate the mechanisms of flow boiling heat transfer and the flow patterns encountered along the tube. The effect of oil on the flow patterns and heat transfer characteristics will be examined. An experiment facility has been design and constructed to allow both accurate measurement of the heat transfer rates and pressure drop and also visual observation of the flow characteristics (see Figure 3). The parameters that will be examined include: heat flux (0-500 kW/m^2) mass flux (50-700 kg/m^2 s) evaporating temperature (-10 – 20 ^{o}C), quality (0-1) and oil concentration (0-10%). Two different oils will be examined (Castrol SW32 and Emkarate RL100S).

Figure 3 Experimental facility for flow boiling of refrigerant-oil mixtures

Experimental study of flow boiling heat transfer in small to micro diameter tubes

Researcher: Xiaorong Huo
Supervisory team: Prof. T. G. Karayiannis, Dr. Y. S. Tian HTFS, Hyprotech UK and Dr. V. V. Wadekar HTFS, Hyprotech UK
Funding: ORS award, London Refrigeration Society £1000

The rapid development of practical engineering applications for micro-devices, micro-systems, advanced material designs and manufacturing is increasing the demand for better understanding of small and micro-scale heat transport phenomena and is causing a notable shift of thermofluid science and heat transfer research from macro-scale to micro-scale. An application of particular importance is compact heat exchangers and their increasing use in two-phase applications. However, research in flow boiling in small diameter channels is still at the very early stages and much effort is needed to clarify the fundamental physical phenomena, and obtain working correlations.

An experimental test rig has been designed and constructed (see Figure 4). Steel test tubes with inside diameter ranging from 1.1 to 4.3 mm have been prepared. The whole facility has now been commissioned and the measuring equipment/sensors carefully calibrated as appropriate for these small-scale experiments. The particular project objectives include a detailed and systematic study of the effect of diameter from conventional to micro on heat transfer rates and pressure drop. Correlation equations will be developed to calculate both heat transfer (including CHF) and pressure drop in these passages.

Flow patterns of flow boiling in vertical small to micro diameter Tubes

Researcher: Lejun Chen
Supervisory team**:** Prof. T. G. Karayiannis, Dr. L. Cheng, Dr. Y. S. Tian HTFS, Hyprotech UK
Funding: EPSRC £51K, SBU Scholarship

Study of two-phase flow in small channels is receiving increased attention in recent years due to its high heat transfer area to volume ratio and the rapid development of micro-devices. The study of flow patterns plays an important role in revealing the mechanism of flow boiling heat transfer. To date, the study of two-phase flow regimes in small tubes is still at its infancy. The existing correlations cannot predict the flow patterns accurately. Thus it is imperative to conduct a study in this area so as to develop new models and correlations for small channels. An advanced experimental rig has been designed and constructed (see Figure 4). It is currently being commissioned. The existing facility can cover a wide range of temperature, pressure, mass flux and quality. The range of parameters that will be included in the current research are summarized as follows:

Fluid	R134a
Pressure	p = 0.2 – 1.5 MPa
Temperature	t = -10.14 – 55.26 □
Diameter	D = 1.1, 2.0, 2.9, 4.3 mm
Orientation	Vertical upward
Gas superficial velocities	u_g= 0.0-6.0 m/s
Liquid superficial velocities	u_l= 0.0-5.0 m/s
Quality	x = 0.0 – 1.0
Void fraction	α= 0.0 – 1.0

The particular project objectives include a detailed and systematic study of the effect of diameter from conventional to micro on flow patterns and pressure drop. The results will be compared with the heat transfer results obtained in a parallel study. The deliverables of this part of the work will be flow pattern maps, which clarify the effect of diameter.

Figure 4 Experimental facility for flow boiling in small to micro channels

Modelling and experimental investigation on a low-pressure solar desalination plant

Researcher A.K.Lalzad
Supervisory team: Prof T.G. Karayiannis, Dr I.W.Eames (Nottingham University) and Dr G. Maidment .
Funding: Council for assisting Refugee Academics (£16K)

The availability of fresh water is imperative for the development of every country and in many places around the world this valuable resource is limited. The solution to this problem is one of the most challenging ones facing engineers and scientists. One way forward is the use of desalination plants. However, the cost of purchasing, operating and maintaining conventional desalination plants is beyond the reach of many developing countries. Hence, there is an urgent demand for new methods of water production in order to satisfy current needs. Suitable plants for these countries must be of low capital and operating costs, simple in operation and maintenance and make use of a non-conventional energy input source, at satisfactory efficiency levels.

An innovative solar energy driven desalination system working at low pressure is currently examined. The novelty of the process lies in the reduction of the pressure due to the height of the evaporator which is 10m, allowing a much reduced grade of energy required to operate the cycle. In a real plant, solar energy can be utilized, thus eliminating the need for conventional thermal energy input. The use of low-grade solar energy for desalination processes is likely to play an increasingly important part in the production of drinking water and in places where high insolation is available and conventional energy sources are prohibitively expensive. The proposed desalination system is shown in Figure 5. Seawater is pumped from a seawater storage tank (6) level to the evaporator vessel (1) 10m above it using a small pump (7). It passes through a condenser (3) where it receives heat from the condensing steam. It then flows through the heater (10) where it achieves the required temperature for evaporation, before being sprayed through the shower (8) to the inner of the two evaporation chambers. The steam rises, condenses on the outside of the condenser and is finally collected in the distillate tank (5). The remaining brine returns to the seawater tank for recirculation.

A mathematical model was first produced which described the thermodynamic process and the desalination cycle. This was used to predict the performance of the plant. It was also used to evaluate the effect of parameters such as water flow rate, temperature, heater output (this simulates the solar collector) and the rate of gas release in the chamber and its effect on pressure and thus performance. A prototype plant is now nearing completion. This will be used to verify the viability of the proposed method and also validate the model. The model can then be used in various locations around the word with different insolation values.

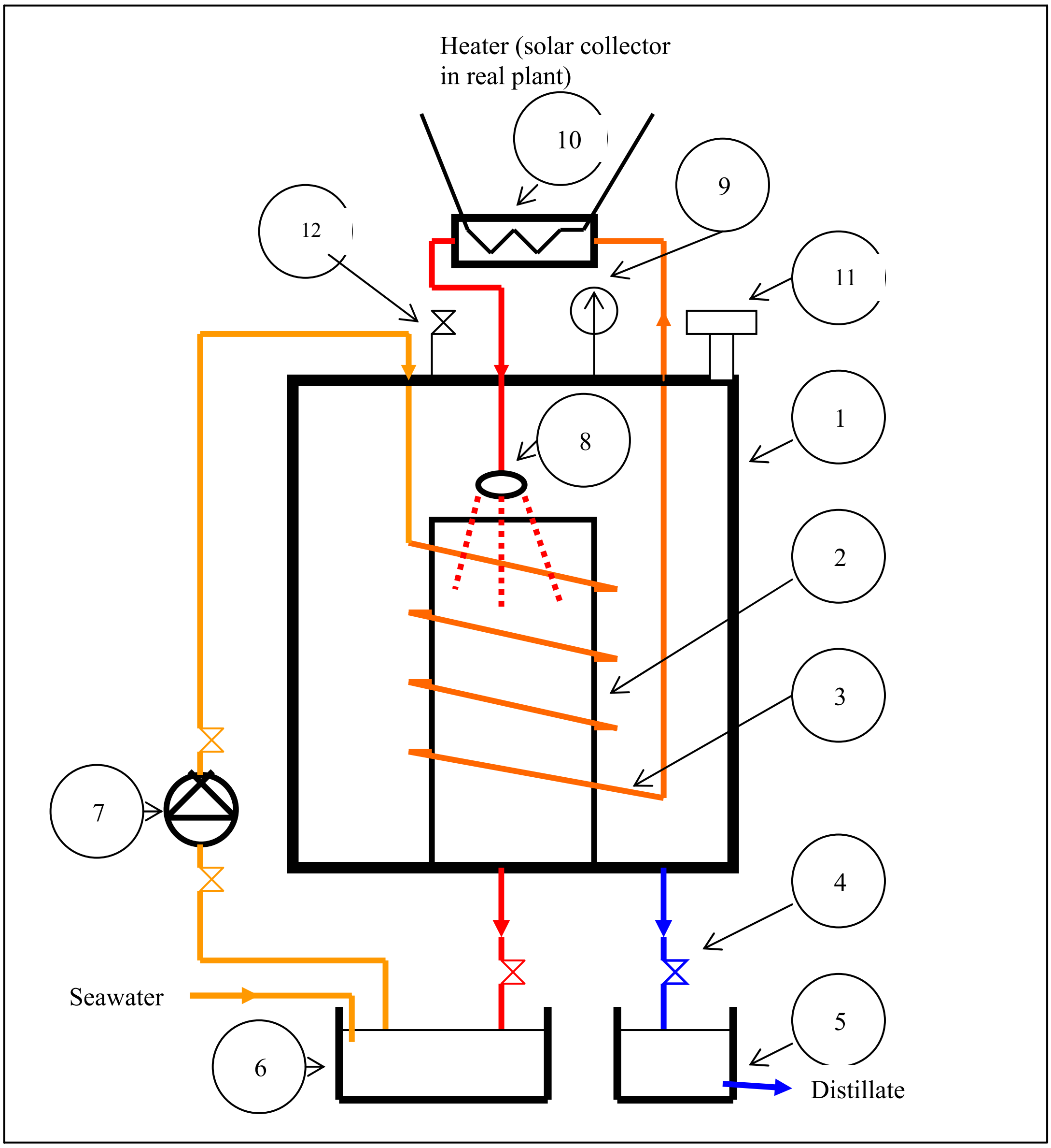


Figure 5 Schematic diagram of low-pressure desalination plant

1 and 2 - Evaporator, 3 - Condenser, 4 - Valve, 5 - Distillate Tank, 6 - Seawater Tank, 7 - Water Pump, 8 - Shower, 9 - Pressure Gauge, 10 - Heater, 11 - Filling Plug, 12 - Air Outlet Valve

Numerical study of the cooling flow regime in umbilical air-fed pressurised suits

Researcher J. Dokhan
Supervisory team Prof. T. G. Karayiannis, Prof M. Collins and P. Edwards, UKAEA Culham Harwell
Funding UKAEA £16 K plus EPSRC Quota Award

It is human nature to avoid situations that involve discomfort and difficulty. This may explain why workers often balk at wearing protective clothing. “its too bulky and hard to work in”, “I get hot and sweaty after I have worn it for a while”, “I have to be careful not to tear it”, “It makes my job twice as hard to do”, “Why do I have to be so uncomfortable to be safe?”. These are all too familiar complaints from today’s workforce, where workers focus on efficiency and productivity and are reluctant to accept anything that might hinder job performance. The potential trade off between comfort and protection is cause for concern, especially among workers who must wear protective apparel while performing physically demanding jobs, and whilst working in hot and humid environments. A leading discomfort factor frequently associated with protective apparel is its contribution to heat. The barrier fabrics used for today’s protective garments tend to retain body heat and humidity and unless sufficient airflow is provided, the worker can become seriously overheated. Nuclear, Biological and Chemical (NBC) are the normal applications of these protective clothing and its uses tend to be either military warfare or research. The focus here will be on nuclear protective clothing within research applications. This having been said it is clear that protective over garment is designed to allow the wearer to operate in nuclear environments offering full nuclear protection. They work in conjunction with respirator systems. Ideally the protective clothing must be lightweight and flexible with limited Thermo-Insulating properties to ensure that the wearer can move unhindered without overheating.

Fusion occurs between the nuclei of two isotopes of hydrogen; Deuterium and Tritium, combing to form heavier nuclei whilst releasing energy in the process. To sustain this fusion process the fuels must be heated to 100 million ^{0}C changing its state to plasma. This process is contained within a Tekamah (Magnetic Steroidal Chamber). The neutrons produced by the fusion produce high amounts of energy that interact with the walls of the chamber changing the characteristics of the wall material and thus activating them. The wall material is commonly beryllium (sometimes graphite) plates and most of its compounds are toxic and its use and handlings are governed by rules and regulations. This degree of risk requires that during decontamination or shutdown periods of the toroidal chamber the worker is required to wear fully pressurised suits.

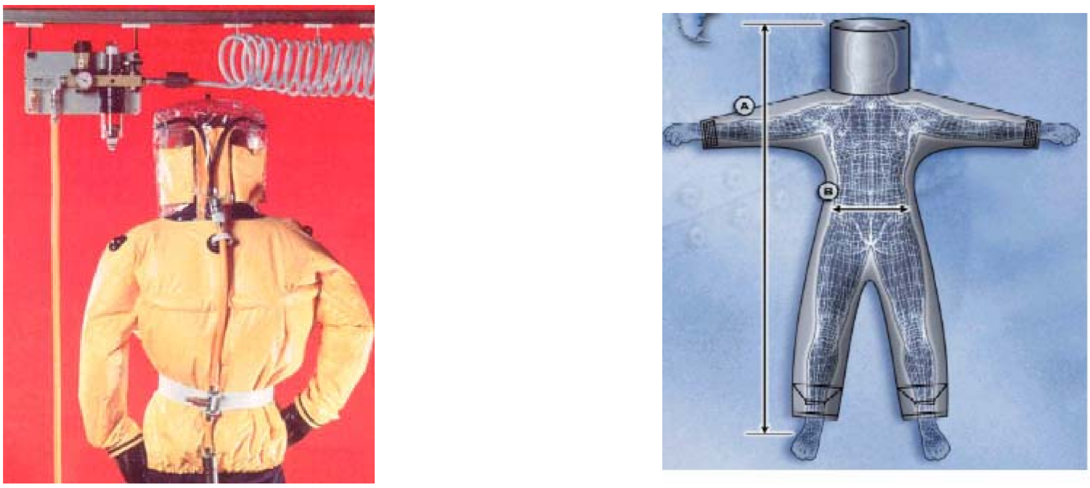
Little or no numerical analysis has been conducted within this field. Its problems however can be approximated to those encountered of NBC protective clothing used in military applications. Where in operating situations high energy consumption must be compensated for with intense heat production. If this were carried out in a hot climatic zone, as is often the case, there is danger to the thermal balance and at times resulting in ***heat stress***. It has been commonplace to model the geometry as two dimensional cylindrical human body parts covered by protective clothing, and the flow as steady. The resulting geometry is often three-dimensional and the associated flow is more complex, being predominantly transient and asymmetric in nature. Since the geometry is known to affect the fluid mechanics as well as the convective heat and mass transfer through the clothing, we believe it to be mandatory to construct realistic geometries based upon realistic figures so as to correlate the fluid mechanics with the genesis of heat strain and the development of any further anomalies.

The principal aim of this thesis, unlike any before it, is develop an understanding to the three dimensional nature of the fluid mechanics and the underlining heat and mass transport mechanism associated with it within pressurised suits. In pursuit of these aims the following objectives were set:

- Numerical simulations of two-dimensional flow around circular cylinder covered by a porous medium. As a matter of code validation.
- Comprehensive numerical studies on three-dimensional realistic human, covered by a pressurised suit whilst in different static working positions.
- Obtain an understanding towards the wall distensibility of the pressurised suit and the resulting effects on the fluid mechanics.
- Numerical analysis of a dynamic model of human within a pressurised suit.
- Achieve a detailed understanding of the fluid mechanics within the respirator system.

The parameters which will be examined are as follows: (i) inlet air temperature, (ii) max flow rate (iii) internal pressure (iv) volume change of suit and (v) different loads of activity levels

A description of the pressurised suit under investigation is detailed below in Figure 6 (a) & (b) courtesy of PLYSU Protection Systems.



a) Air Fed System of pressurised suit **b) Schematic of pressurised suit**

Figure 6 Pressurised suits

The evaluation of cooling degree-days and their applicability to building energy analysis

Researcher: Dr T Day
Collaborators: Dr Ian Knight, Welsh School of Architecture
Gavin Dunn, Welsh School of Architecture
Roger Hitchin, BRESEC
John King, University of Western Australia

This research is being conducted in collaboration with the Welsh School of Architecture (WSA) the BRE Sustainable Energy Centre (BRESEC), and the University of Western Australia (UWA) into the use of cooling degree-days in energy estimation and analysis in buildings. Energy estimation is becoming increasingly important due to the requirements of the 2002 Building Regulations, the emphasis in the recently published energy white paper on energy efficiency, and the impending EU Directive on energy labelling of buildings. Heating energy analysis is relatively well defined, and good practice guidance already exists in this area. However, cooling energy analysis is more complex due to the variety of cooling systems that exist, and the combination of both sensible and latent loads.

The theory of cooling degree-days has hitherto been defined in a similar way to that of heating degree-days, but evidence of their use in practice has shown this approach to be inaccurate. In any case close scrutiny of this definition shows it to be deeply flawed. Work at South Bank University has been published recently to show a more rigorous definition based on en energy balances conducted around the cooling element (see Figure 7 and Figure 8). However rigorous this theory may be, it needs to be verified and, more importantly, shown to be of practical value. This project will analyse high resolution, high quality cooling energy data sets in order to:

1. Verify the theory of cooling degree-days.
2. Develop practical guidance on their use where this is appropriate.

Data is being collected by WSA of a substantial number of building cooling systems, including high resolution energy and temperature data. The value of this data has been estimated at £200,000, and is being made available to South Bank under a collaboration agreement for the purposes of this work. Such data has not been previously available to enable detailed analysis of degree-day techniques. Figure 1 shows an example preliminary analysis of one data set, used to identify the building energy balance point; this example shows good correlation between energy and temperature.

In addition data is being provided to South Bank from UWA to enable a practical evaluation of cooling degree-day analysis techniques in the monitoring and analysis of building cooling systems. Preliminary results show the good relationships between energy use cooling degree-days, when the latter are determined according to the theory developed at South Bank. Figure 2 shows such a correlation of energy against degree-days where individual monthly base temperatures are used. The next step is to develop practical guidance on the use of this methodology.

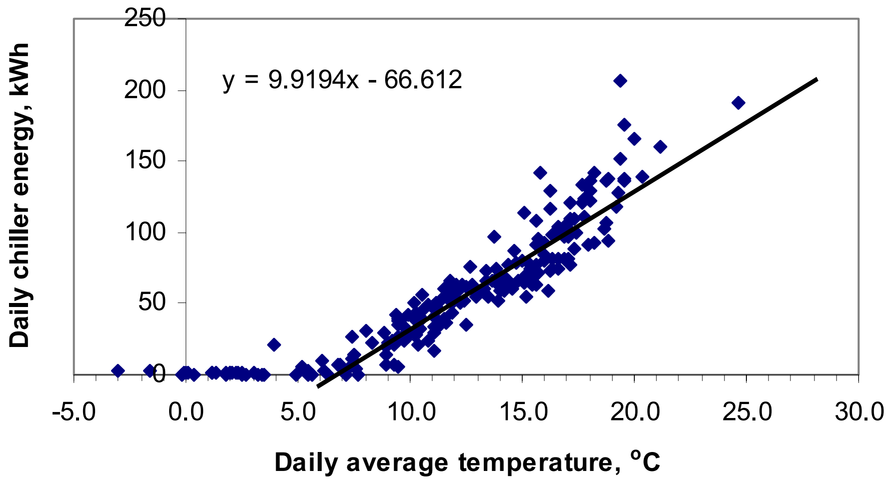


Figure 7 Daily energy signature for a chilled ceiling system, showing the outdoor balance temperature at zero energy consumption

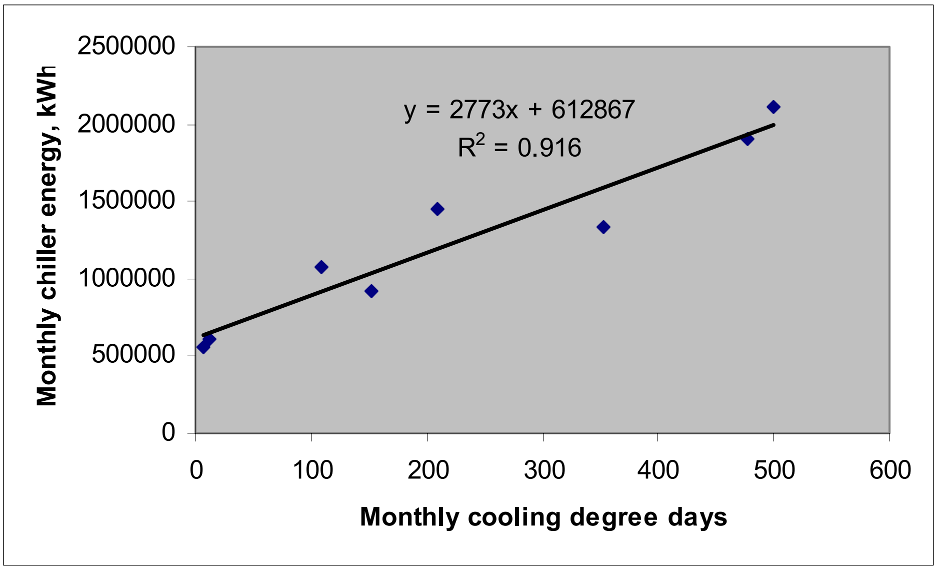


Figure 8 Cooling energy performance line for UWA, Perth Australia, using degree-days defined for individual monthly sensible and latent coil loads

Decision support systems for sustainable energy planning in a developing economy

Researcher: Titus Kehinde Olaniyi BSc, MSc.
Supervisory team: Dr. A.R. Day, Prof. T. G. Karayiannis, Mr. M. Kennedy and Prof. R. O. Fagbenle (University of Ibadan)
Funding: This Research programme was part funded by the Engineering and Physical Sciences Research Council.

Developing Economies (DE) are undergoing dramatic changes in their adaptation of new socio-economic and technological policies which includes liberalisation of the energy markets, financing of energy projects and the incorporation of externalities such as the environmental implications of energy projects. However, many DE are struggling with political, economic, technological and environmental instabilities. Instabilities are the main causes of non-linear dynamics that impinge on their ability to develop their energy systems in a sustainable manner. Given this dynamic complexities of energy systems in DE, this research proposes a generic methodological framework titled “Dynamic Energy Systems” (DES) paradigm- a Decision Support Systems Framework using a System Dynamics (SD) modelling taxonomy for sustainable energy planning.

Given the inherent energy systems structure, current trends and future forecasts in the DE, there are complex implications that need addressing in the applications of traditional planning tool to sustainable energy planning and policy formulation. The unsuitability of traditional tools to DE is rooted in the well-pronounced socio-economic, political, technological, and environmental gaps, as compared to those of the Organisation for Economic Co-operation and Development (OECD) nations where the tools were originally developed and intended.

This research reviewed traditional planning approach such as optimisation, econometric and general simulation tools for energy policy and addresses their inherent limitations in DE. It argued that the advocated strength of traditional approaches are significantly impaired when applied to DE where socio-economic, political, technological and environmental objectives are often multidimensional, dynamically complex and seldom has a clear definition. DE lacks reliable socio-economic and energy data. Hence, the rational determination of the objective function is often unclear. Traditional energy planning approaches are inappropriate in DE as it focuses on present decision without identifying how past policies created the present dynamic complexities. In summary, traditional energy planning approaches fail to demonstrate to the relevant energy policy measures that will guide future outcome of the present energy options and decisions.
Various authors have reported that past energy development trends witnessed in the OECD nations contradict the notion of sustainable energy developments. It is of paramount importance that energy planner and their advisers in DE integrate into their planning paradigm such dynamic and non-linear complexities that are predominant in the DE but however not likely in the present in OECD nations. This research emphasise that the application of traditional energy planning and modelling approaches to DE in its present context is a hypocritical gratification of inappropriate technology. Hence, DE requires a paradigm shift in understanding and planning for sustainable energy development.

The economic and practical implementation of off-grid rural electrification

Researcher: Jeyatharshini Jeyabalasingam
Supervisory team: Dr T. R. Day Prof. I M Dharmadasa – Sheffield Hallam University, Prof. Tassos Karayiannis
Collaborators: Commonwealth Science Council
Funding: South Bank University Scholarship

The research in progress is aimed to address the economic and practical implications of the introduction and promulgation of renewable energy technologies in Sri Lanka. This is achieved by the construct of a model using Systems Dynamic software and the Logistic Curve to determine the sensitivity of market saturation with the following objectives:

- To show the scope of rural electrification in a developing country.
- To evaluate alternative generation technologies.
- To recreate the behaviour of that market in terms of existing policies and structure.
- To determine the value of individual electrification projects.
- To determine the rate of uptake of RETs for different sets of conditions.
- To determine location sensitivity of the cost of electrification in rural areas (life-cycle cost analysis).
- To improve system's behaviour by suggesting alternative delivery mechanisms.

The expected outcome of the Logistic Curve and Systems Dynamics as developed in this project may suggest the right mix of supporting institutions, reforms, policies, markets, and infrastructure needed for rural energy development in a particular country under the specified circumstances. This includes the right pricing structures, efficient power sector management, viable lending institutions, credible regulatory policies and solid legal frameworks. This analysis should ultimately enhance the understanding of the potential contribution of off-grid rural electrification to energy planners and policy makers, their advisors, investors as well as manufacturers and installers of electricity systems in the specified country.

The development of a dynamic model to simulate boiler controls

Researcher: X. S. Damianos
Supervisor: Dr. T. Day
Source of Funding: Self-Funded

Despite the widespread use of boiler plants for low-pressure hot water heating and many years of experience with these systems, there is still no generic guidance on how the boiler plant as opposed to the heating system should best be controlled. Furthermore, boiler control dynamics understanding is still incomplete, despite the recent years claims that energy can be saved by suppressing boiler cycling rates.
Moreover, no theoretical treatment has been published that describes the relationship between boiler firing patterns and energy consumption as well as the ability to maintain levels of service.

This project therefore is based on the development of a model that will simulate boiler controls so that all the various aspects of boiler control strategies can be investigated. This will lead to better understanding of the firing patterns as well as of the key factor(s) that affect the boiler operation. By improving the operation, the efficiency will be improved as well and also, it is essential that the question of stable, reliable and economic control is resolved. Furthermore, this will reduce the UK's CO_2 emissions.

The model is based on Excel using Visual Basic for Applications to perform all the calculations, where the user can modify all the parameters according to their requirement and obtain the result from various graphs and data tables. Currently, there are four different boiler models, consisting of One, Two, Three and Four Boilers each, but mostly the Three and Four Boiler models are been used, for controls simulation and analysis of operating parameters as well as for investigation of new techniques that can be implemented to the model which will lead in reducing the fluctuations of flow & return temperatures and thus improve the overall efficiency and reduce gas consumption.

Validation of the model will follow later on, by installing an experimental boiler rig and by applying in real time the techniques found from the theoretical model, the emulation of different building and system response strategies will take place.

A validated theoretical exposition of how the boiler-firing patterns affect energy consumption, together with generic guidance of the positioning and setting up criteria for control devices, will be the final outcomes of this project.

Further work will involve mathematical optimisation, putting together all relevant information and writing up of the PhD thesis.

MSc Building Services Engineering (Flexible provision)

Project leader: TC Dwyer
Funding: EPSRC £240K

This project is the development and production of the multimedia e-learning materials for the MSc Building Services Engineering (Flexible provision) Course. South Bank University is the largest provider of undergraduate, post-graduate and CPD courses in the UK building services sector. The development of this package will allow a greater range of people to access the skills that the University has to offer whilst maintaining the high quality of education and training provision.

The building services group has already developed two CD ROM based learning units that are currently being used on a number of courses and would be integrated into the final programme. The proposed training package will build on this experience to allow flexible access to all or part of a post-graduate programme

The Multimedia e-learning materials to be produced are to support the following modules:

Four Primary core modules:
1. Building Environmental Space
2. Building Energy Systems
3. Management
4. Research Methods

Up to five optional modules from the following list:
1. Energy Resources Utilisation and Economics
2. Air Conditioning Analysis
3. Building Services Engineering
4. Electrical Services
5. Refrigeration
6. Lighting

Acoustic design guidelines and teacher strategies for optimising learning conditions in classrooms for hearing and hearing impaired children

Researchers: Anne Carey (Acoustics), Anastasis Efentakis (Acoustics), Kate Rigby (Psychology), Institute of Education
Supervisory team: Prof. Bridget Shield, Prof. Julie Dockrell, Institute of Education, London University
Collaborators: Arup Acoustics
David Canning (City University)
Voice Care Network
AMS Acoustics
Funding: EPSRC Research Grant under EQUAL (Extending Quality of Life) initiative Value of award: £320,000 (£155,000 SBU; £165,000 Institute of Education)

The aim of this project is to provide data and information to aid and underpin the development of acoustic guidelines and teacher strategies for optimising learning conditions for hearing and hearing impaired children in primary schools. The project is a joint, multidisciplinary project involving acoustics, psychology and audiology and is being supervised by Professor Bridget Shield at South Bank University and Professor Julie Dockrell at the Institute of Education, London University.

The project follows on from a two-year project, funded by the Department of Health and Defra, carried out by Professors Shield and Dockrell, which was completed in 1999. This project investigated the effects of noise in the classroom on primary school children in London, by a combination of noise surveys, questionnaire surveys of pupils and teachers, testing of children in different noise conditions and comparison of noise levels with school scores in standardised assessment tests (SATs). The main conclusions of this project were as follows:

- Children in London primary schools are exposed to higher levels of noise at school than recommended by current guidelines
- External and internal noise levels are negatively correlated with school SATs scores
- Classroom noise is dominated by class activities, rather than external noise
- Children are aware of noise and annoyed by specific sound sources
- Children are aware of difficulty in hearing the teacher in certain circumstances
- Children's reported levels of noise occurrences are related to objective noise measures
- Acute exposure to noise affects performance on academic tasks
- Children with special educational needs are differentially negatively affected by classroom noise than other children.

The current project continues and extends the previous work to investigate the acoustic conditions of classrooms; the most efficient and effective methods of improving classroom acoustics; the effects of noise and poor acoustics on teachers' voices; the use of sound field systems in the classroom and the effects of noise and poor acoustics on all children, including specifically hearing impaired children. The project consists of noise and acoustic surveys of classrooms; questionnaire surveys of pupils and teachers; cognitive testing of children; surveys of teachers' voice levels; development of speech intelligibility tests for children; and studies of soundfield systems in use.

The research is being undertaken in primary schools in London and Hertfordshire.

There is widespread dissemination of the work on noise in schools and there was considerable media interest when the final report for the Department of Health was published in April 2002. Professor Shield was invited to a workshop at the University of British Columbia, Canada in January 2003 to discuss the findings, and to address a meeting of architects at the RIBA in March 2003; Professors Shield and Dockrell have been invited to an international audiology conference in Chicago in November 2003; and Professor Shield has been invited to speak about the work at the British Association Festival of Science to be held in September 2003. The research team is to present four papers on the current project at the international acoustics conference 'Euronoise 2003' in Naples in May 2003.

Sustainable groundwater cooling system for the London underground tube network

Post doctoral Researcher: Dr Felix Ampofo
PhD Research Scholar - Vacant
Supervisory team: Dr Graeme Maidment and Dr John Missenden
Funding: London Underground Limited £35K, HEFCE £15K, EPSRC £50K

The operation of London underground tube network can generate enough heat to raise tunnel and station temperatures substantially. This may result in passenger discomfort in warm weather conditions if the underground tube environment is not cooled. Ventilating the underground tube environment in which there is heavy traffic of electrically propelled rapid transit trains differ from those normally encountered in conventional air conditioning. The heat generated by the train motors and electric lighting, together with body heat from passengers, is so great that excessive temperatures would prevail in summer unless a high volume of air is supplied. This is difficult to achieve in London underground tube network because of old infrastructure. The installation of in car air-conditioning units adds another major heat release source in the tunnel, which must be ejected to the ventilation air. Also, the rising water table in London is a problem to some parts of the London underground tube network. The water leads to a serious deterioration of track, traction supply and signaling systems.

This research investigates a novel cooling system that aims to reduce the water table by using the groundwater for ‘free’ cooling the London underground tube network (see Figure 9). Figure 1 shows a schematic diagram of groundwater cooling. The concept of groundwater cooling is as follows: groundwater is pumped through heat exchangers; hot air in the London underground tube network is cooled and then circulated by fans onto platforms; trains act as giant pistons which will circulate the air around the London underground tube network; fans on top of trains suck in air to cool trains. The principal objectives of the proposed research are:

1. Investigate thermal comfort on the London underground tube network.
2. Investigate the use of groundwater cooling for the London underground tube network.
3. Produce a prototype design for cooling a specfic site within the London underground tube network.

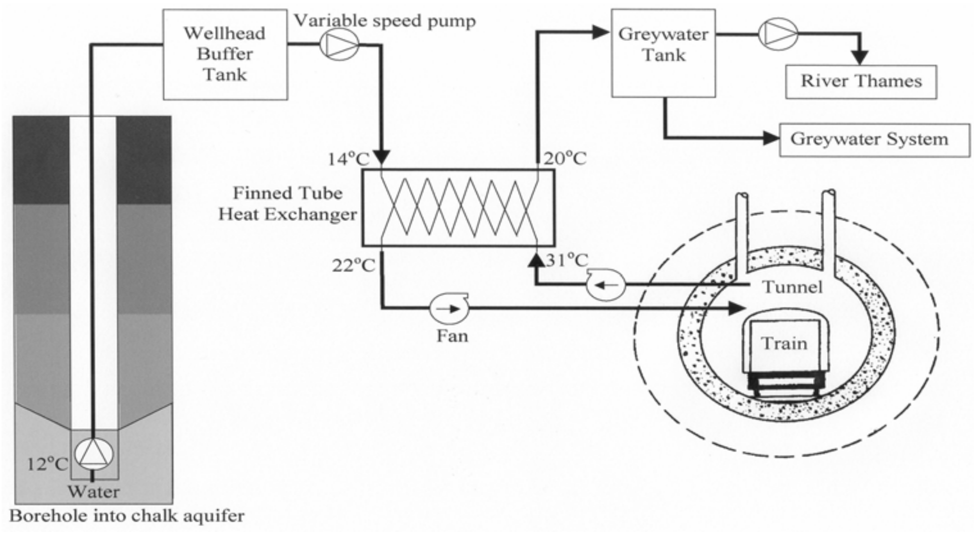


Figure 9 Schematic diagram of groundwater cooling

Optimal Solar Cooling Systems

Researcher: A. Syed
Supervisory team: Dr G. G. Maidment, Dr. J. F. Missenden and Dr-Ing. R. M. Tozer
Source of Funding: South Bank University Research Scholarship

The cooling requirements and occurrence of solar insolation are approximately proportional, which makes solar-cooling a practical approach in modern building design. However, low thermodynamic and economic performance of existing solar cooling plant has been repeatedly reported in the literature, with great deal of scope for technological improvements. The main source of inefficiency and economic penalty associated with solar cooling components are those related to the available designs of solar collectors and absorption chillers. The key to the successful application of solar cooling lies in the implementation of measures to improve the design and application of solar collectors. This task is difficult to achieve without an accurate mathematical model to predict the first and second law of thermodynamic performance of the collector.

The area of novelty in the research is to create a detailed understanding of the various loss mechanisms that render real low temperature solar collectors uneconomical, using the concept of available energy as a performance indicator, since the cost of energy sources are proportional to a much closer degree to their exergy content. The exergy model of the collector will be combined with that of absorption chillers to investigate the effect of various environmental parameters of solar insolation, ambient temperature and relative humidity, and location parameters related to latitude and solar trajectory. The mathematical model of the collector and chiller are to be validated numerically and experimentally. From there, to optimize the exergo-economic (thermoeconomic) performance of the collector fin and tube arrangement and the overall design of the solar cooling system. This will result in novel optimal globally applicable guidance for research, consulting and manufacturing concerns. The optimization will result in cost effective designs of solar cooling systems.

To date, the mathematical models of the preferred collector and cooling system have been developed and integrated using the Engineering Equation Solver computer package as shown on Figure 10. The size of the collector field and the cooling capacity of the refrigeration machines vary in relation to the available roof area for solar energy collection and building cooling load. These have been numerically validated with empirical data obtained from the literature.

Further work will involve experimental validation, mathematical optimization, collation, writing up of the PhD thesis and publications.

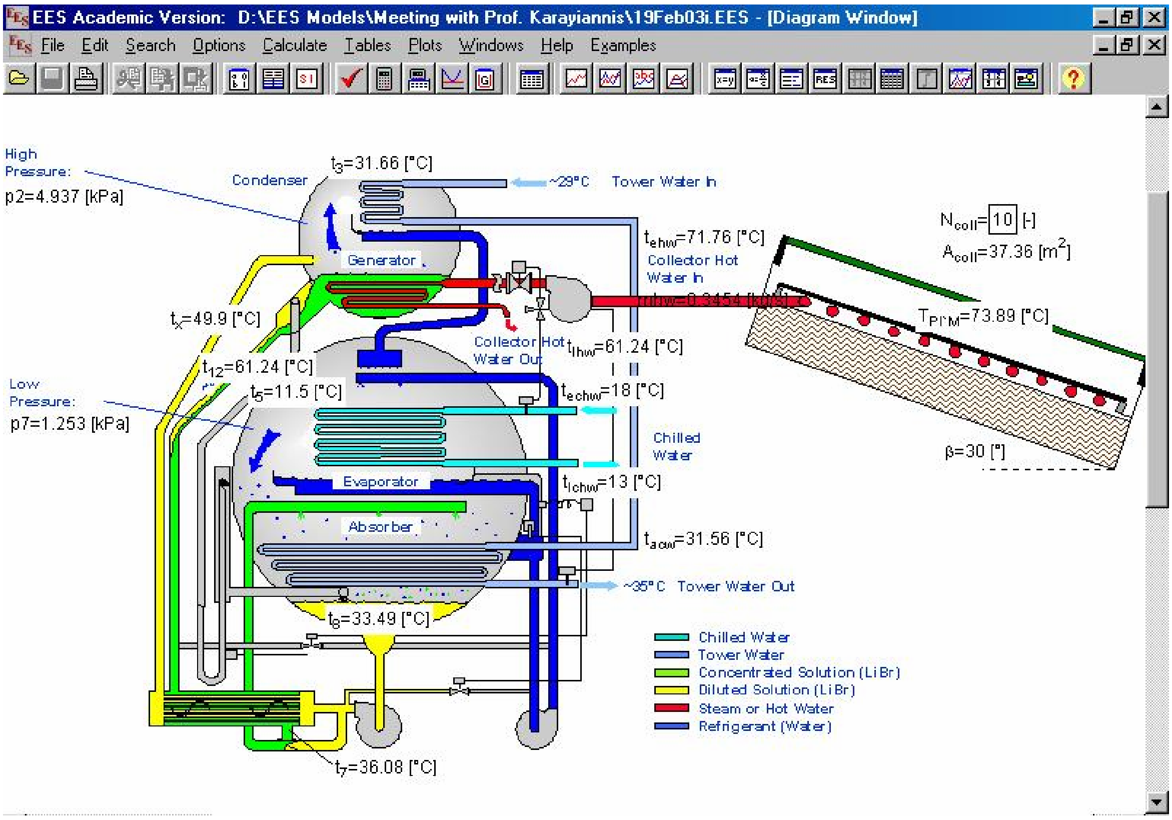


Figure 10 Schematic of proposed solar cooling system design

The passive use of phase change materials with in refrigeration system

Researcher: Fuqiao Wang
Supervisory team: Dr. G. Maidment Dr J.Missenden and Dr R. Tozer
Funding: EPSRC, £65K

Refrigeration is a major consumer of electricity in the UK; this constitutes about 17% of the total UK energy use. Whilst refrigeration machinery is selected to satisfy the design consideration, option at full load usually occurs for only a few hours per annum and for most of the year refrigeration systems operate at part load. In many cases the port load efficiency of the refrigeration plant is much less than the optimum and this is often because of excessive superheat and mechanical condenser pressure control, which are necessary to make the system running in stability. This is the main reason for most of low efficiency refrigeration systems.

Phase change materials (PCMs) with the potential to store and release massive amounts of energy at constant temperature provide an opportunity for stabilizing system performance as well making large energy savings. This is achieved by integrating the PCMs heat exchangers into the system, shown in Figure 11, sub-cooler and super-heater are PCM heat exchangers), a sub-cooler is arranged to offset the inefficiency caused by higher condenser pressure, a super-heat is arranged to offset the inefficient TEV control, the initial results from the mathematical model and experiment are shown significant improvement.

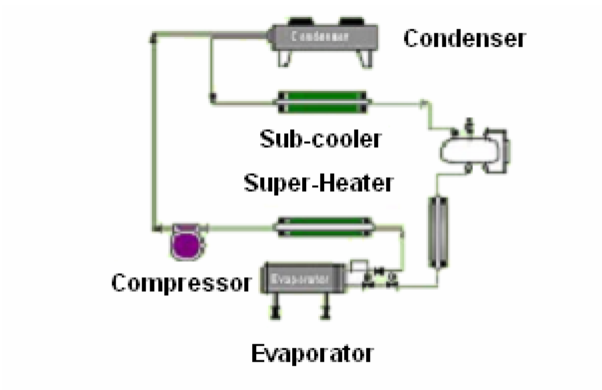


Figure 11 Refrigeration system with passive use of phase change material

The specific objectives of the project are:

1) Investigate the most appropriate phase change materials for passive use in refrigeration system
2) Develop a mathematical model for this purpose
3) Optimize the PCM heat exchangers
4) Develop and test a prototype system using PCMs

Advanced Refrigeration Systems and Components

Researcher: Vacant
Supervisory Team: Dr. G. Maidment Dr J.Missenden
Funding Present: Eu 1000 (seeding) Alfa Laval plc, Previously £130, 000 (At Leeds and South Bank University)

This project comprises a multifaceted investigation into components and system behaviour of industrial refrigeration systems, with a view to enhancing significantly their energy performance. The review includes evaporator performance with both single and two-component refrigerants, using modern plate exchangers with novel flow patterns. A PhD project supported by Alfa Lval has been successfully completed and the test rig resited for extension of the work. An MSc project has also been successfully completed and future work wil concentrate on testing, modelling and rating the novel surface.

A further aspect to be examined is the series of non-idealities which occur in real systems, remedying which is generally not attempted. An integrated approach to system upgrade is to be examined which it is envisaged will produce an advance in energy and exergy conservation in such sytems. Plant has been provided by Airedale Refrigeration, which is also collaborating with rig design and framework

Cogeneration in Conventional Power Stations

Researchers: Dr H. Goshayshi, Dr J. Missenden, Dr G. Maidment, Prof T.G. Karayiannis
Funding £17K – The Carbon Trust

Electricity is generated using conventional thermal systems based on the Carnot Cycle, using fossil, bio-fuels, nuclear reactors, gas turbines, CCGT and sustainable sources such as hydro, wind, wave and PV. Conventional electricity generation has two salient problems; the high carbon emissions from fuels like coal, which are amplified by the low quoted conversion and the low overall efficiency (33%). UK industry discharges over 100 PJ/s of low grade waste heat (25ºC to 250ºC) from electrical power stations. A technology to recover or convert this low grade waste heat to usable, high voltage electricity could save industrial sectors tens of millions of pounds annually, through increased process efficiencies and reduced fuel costs, while substantially reducing greenhouse gas emissions. During the past decade, there has been unprecedented research interest in power plant to reduce CO_2 emissions but the literature survey indicated no published work on the use of waste heat from the condenser.

The object of the study is to investigate this and this will enable improved decision making about the use of ‘‘waste’’ heat from large scale electrical power generation, in particular that fired by coal, the highest carbon emitter. This project will embody the following features; a position statement of the current UK situation, an analysis of the energy conversion cycle, uses of presently rejected energy, particularly in power plant, case studies and mathematical modelling. The project will identify savings in energy through more intensive use of existing combustion.

To increase the thermal efficiency of the power station the following steps are necessary:

1) Thermal power stations based on coal has low thermal efficiency; some of 67% wasted heat can be recovered from the condenser. Investigation the use of energy in coal fired power stations on improving the Rankin cycle efficiency is our second goal.

2) Case studies must be made using actual plant and data

3) The main aim of this investigation is for improving efficiency especially the use of the rejected condenser heat for power stations which is next step of our work by studying the present methods to use from the rejected heat in condenser and bring the new method for improving cycle.

4) The data gained in stage 1 & 2 will be used to develop mathematical models for an exergy analysis of a single or double effect absorption refrigeration cycle. Therefore, in order to determine the heat and mass transfer as well as the thermodynamic properties of the components, each component will be taken as a single unit, the balance equations of mass, energy, entropy, heat transfer and exergy balance can be found.

A Novel Superconductive Food Display Cabinet

Researcher – Vacant
Supervisory team: Dr. G. Maidment Dr J.Missenden and Prof Karayiannis
Funding – £25K London Business Innovation Centre

Since the salmonella crisis in 1988 the food industry in the UK has suffered with a number of food safety and hygiene problems. The retail part of the food chain has been no exception. In an attempt to reduce the increasing numbers of reported food poisoning outbreaks, new UK food hygiene regulations were introduced in 1990. The focal point of the legislation was that all sensitive foodstuffs be maintained at a temperature below 5°C. Compliance with these regulations caused particular problems in many shop outlets, since existing cabinet designs proved to be unable to maintain temperatures of 8°C, let alone 5°C . Although cabinet designs were modified, tests on these new designs showed that they had difficulty in maintaining minimum temperatures in variable shop conditions, without causing localised freezing somewhere in the cabinet . As a result the food hygiene regulations were subsequently relaxed and higher food temperatures were allowed . Unfortunately, new research has reported that food poisoning cases are increasing rapidly and it was recently estimated that 2 million people in the UK suffer from some form of food poisoning every year . In recent studies of retail display cabinets 70% of the food displayed was reported to be stored above 8°C and 60% was at 10°C or more . Therefore, better refrigeration of food on display is essential if food safety is to be increased.

Retail food cabinets have been investigated by many researchers, however, their design has not changed appreciably from those reported. In these cabinets, the food was stored and displayed on shelves or decks, cooled by cold air, supplied from within the cabinet. The air was circulated through the cabinet using axial fans and the bulk of the air was directed into the display area as a jet, which formed an air curtain across the cabinet opening. The air was then recirculated within the cabinet where it was cooled by a plate fin and tube heat exchanger containing a low temperature refrigerant with a saturated refrigerant temperature of -7°C. The evaporator was in counterflow with the air, which entered the evaporator at approximately 5°C and left at -5°C. .

Although the food is normally delivered to the cabinet at the required food storage temperature, cooling is required to offset gains to the food, which are basically a result of radiant interchange between the food and the retail environment. The cooling load necessary to offset these gains was only a fraction of that delivered to the cabinet. At best, this low proportion of heat transfer rate actually delivered results in excessive energy use, high equipment costs and loss of shelf life. At worst, the low efficiency can result in failure to meet food hygiene temperatures, which can then compromise food safety.

Work carried out by the research team with delicatessen food cabinets showed that it is possible to provide significant additional cooling to the food by positioning the food directly in contact with a cold base. This was achieved by sitting the food on a base in contact with the evaporator. This gave a strong thermal conduction link between food and refrigerant. The cabinet then operates more efficiently and results in significant reductions in energy consumption, as well as improvements in food quality/ safety. Other types of chilled food cabinets could also benefit from this conductive cooling effect. As most chilled cabinets utilise adjustable shelving, enabling conduction heat transfer by sitting the food shelves onto a fixed evaporator surface is not a practical option.

This proposal describes an alternative and novel concept (see Figure 12) that investigates and models cooling to food in order to allow parametric model investigation. There is good evidence to suppose that a conductive link to the shelves of multi-deck chilled cabinets will greatly improve performance. A novel development can allow conductive heat transfer to be introduced into the cabinets. Conductive cooling may be achieved using a super-conductive heat pipe shelf to conduct heat from the food, to be rejected directly to the oncoming cold air stream. Heat pipes have been proposed in a number of refrigeration and air conditioning applications as well as for enhancing freezing and thawing of meat blocks. They reported that the heat pipe provided additional cooling by conduction, to reduce the freezing time by 42% and the thawing time by 55%.

The integration of a low temperature shelf in display cabinets not only allows conductive heat transfer, it also provides a further opportunity to introduce radiative cooling to food on display by the large shape factor between the underneath of the shelf and the food below.

A fundamental investigation of the radiative, convective and conductive linkage between food and its storage environment has not previously been reported. The novel development of a heat pipe shelf has enabled this and this proposal describes such an investigation. It builds on preliminary work carried out by the authors, which identified that the heat pipe shelf would have a significant impact on the equipment energy use /operating costs and food quality in retail food applications.

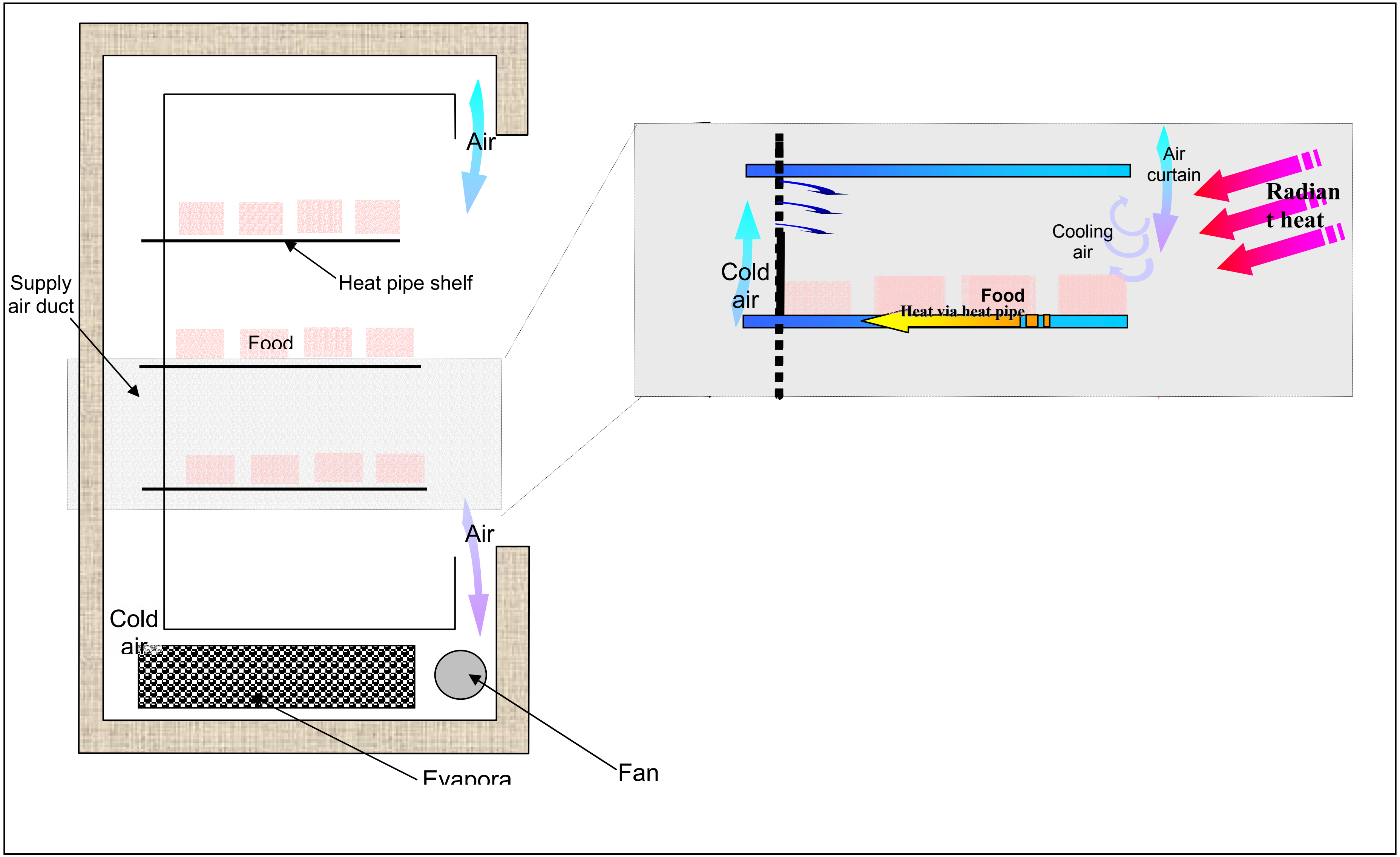


Figure 12. Diagram showing operation of heat pipe cooling shelf fitted to supermarket food cabinet