Building Services & Built Environment Research in the Region

As well has having the very first Building Services Engineering degree course, our Region was unquestionably one of the major Centres for Excellence in relevant research for a period of about 30 years from the mid-1960s. There were two outstanding, commercially funded, research units whose output of significant material was prolific to say the least. These were the Environmental Research Unit at the Electricity Council Research Centre at Capenhurst near Chester, under the management of Dr Geoffrey Brundrett and the Environmental Advisory Service at Pilkingtons in St Helens, under the management of Peter Owens. The work being carried out at these establishments was at least as relevant as anything being done at the then (Government funded) Building Research Station near Watford.

Pilkingtons Research Laboratory at Lathom in Lancashire is not, strictly, within our Region, however, the work there was controlled from St Helens. The Pilkington Research Unit in the Department of Building Science at the University of Liverpool, under Peter Manning, was at the same time, studying office and factory lighting and this work fed directly into the environmental design for the Cooperative Insurance Services (CIS) tower in Manchester, considered by many at the time to be the first office building designed from the inside outwards.

In parallel with Manning's work a very high calibre team was working at St Helens on daylighting and window design. This team included Joe Lynes, Bill Burt, Kit Cuttle and Ken Jackson. Another major aspect of the work of Pilkingtons Environmental Advisory Service was related to the many specialist types of glass they produced and also, under Rick Wilberforce, they would advise on Passive Solar Heating of buildings.

Pilkingtons also produce insulation products and a considerable amount of the research carried out at Lathom was looking at thermal performance of wall assemblies using their guarded 'hot box'.

The research work carried out at Capenhurst was on a different scale from that at Pilkingtons, the Electricity Council Research Centre had a staff of about 300 and as well as high profile, internationally acclaimed research into the human aspects of artificial lighting and thermal comfort, the Environmental Research Unit actually studied energy efficiency in housing by *building* a number of houses. These houses were occupied by families and closely monitored. The Building Research Station at this time was still using electrical simulation of occupancy in buildings it monitored.

During the 1970s and 1980s the local Electricity Board (MANWEB) would regularly provide free seminars for CIBSE members and these usually included presentations about the results of work at Capenhurst. Members in our Region benefitted greatly from this local dissemination of knowledge which was at the forefront of technology and, especially in energy efficiency, well ahead of its time. Presenters would refer to 'The Electricity Council House' in terms of recommended insulation and airtightness standards 30 years before such standards started to be required by the Building Regulations.

The ECRC Environmental Research Unit staff at that time included the following personnel: Peter Boyce (Lighting), Donald MacIntyre (Thermal Comfort), Tony Mould (Housing), Jack Siviour (Thermal Properties), Peter Basnett (Mathematical Simulation), Robert Heap (Heat Pumps) and Don Dickson (Ventilation). ECRC Research Papers were published in considerable numbers and distributed freely to the industry, the work described in these papers was also presented at numerous National and International Conferences. The reputation of this Unit was most definitely worldwide.

Tony Mould describes the work on housing:-

Housing Research at Capenhurst.

The Electricity Council established its National Research Centre at Capenhurst in late 1965, with the brief to research into new and improved methods of distribution and utilisation of electricity.

The research centre at Capenhurst had a complement of 300 staff. The Research Programme originated mainly from problems arising in the twelve Area Electricity Boards and from the need for a fundamental understanding in a particular area, perceived by the centre itself. The staff brought together inter-disciplinary teams that included research minded electrical, mechanical and chemical engineers, together with physicists, natural scientists and life scientists. Together they produced useful and significant results. There was active research in more than one hundred research topics. This is an account of the research carried out at Capenhurst on the particular subject of energy consumption in housing during the years 1967 to 1990.

Houses consume a significant part of the electricity produced, mainly for space and water heating.

Sector	Electricity Use GWh (2004)	Percentage
Industry	117,149	34.45%
Transport	8,034	2.36%
Domestic	115,526	33.97%
Public administration	20,92	6.15%
Commercial	4,215	21.83%
Agriculture	4,194	1.23%

It was evident that house and heating systems were together a single interdependent system whose overall efficiency needed to be improved. Clearly, for electricity to be used more widely, heat loss needed to be reduced. Accordingly it was decided to study house performance, and to seek ways to improve it. The thermal standards of British houses have varied markedly over time, and so have their forms of construction. Another variable has been the life style of the occupants, and their increasing use of energy.

A major programme of research into the energy performance of houses was started in 1967. It was decided to build some representative houses and then to measure their performance. An established three bedroom, two storey, local authority house design by the Midlands Housing Consortium was chosen, and a nearby site found. A row of six semi-detached houses was built, using a common plan. In order that measurements could be made on all six external surfaces of the inhabited volume, each house was drawn apart from its neighbour by two metres to create a roofed and enclosed central space between the two party walls. This arrangement gave access to the loft and to a crawl space under the ground floor of each house. This central void was then used to house recording equipment for ongoing measurements.

The houses, in Manorfield Close, Capenhurst, were numbered 8,10,12,14,16 and 18. Numbers 8, 12 and 16 were timber framed with cavity gable walls, whereas numbers 10 and 14 had masonry cavity walls. Of these, number 16 was highly insulated for the time, to an expected future thermal standard and number 18 had 9” solid brick walls with single glazing, and so represented the many existing older houses throughout the UK.

Although the house design chosen represented the then current UK building standard, detailed improvements were made. The thermal insulation was increased in thickness and made as continuous as possible, such as the loft insulation being extended at the eaves, to connect with the insulation in the wall. The test houses continued to be monitored and to act as a test bed for a variety of heating and ventilation systems for twenty years.

Two national builders, Comben and Salvesen, each built two of their standard speculative house designs to the Capenhurst low energy standard in Leeds and Warrington, in 1982. All four were 80 m^2 floor area. They were sold, and the occupants’ energy use was recorded in detail for the first year.

The new owners initially were apprehensive about the house and its equipment, but later became enthusiastic about them. Generally, besides being pleased about reduced heating costs, their comments centred around the virtues of the mechanical ventilation system, remarking in particular about a dry house with no condensation or the need to open windows in winter.

Window opening can have a profound effect on the cost of space heating

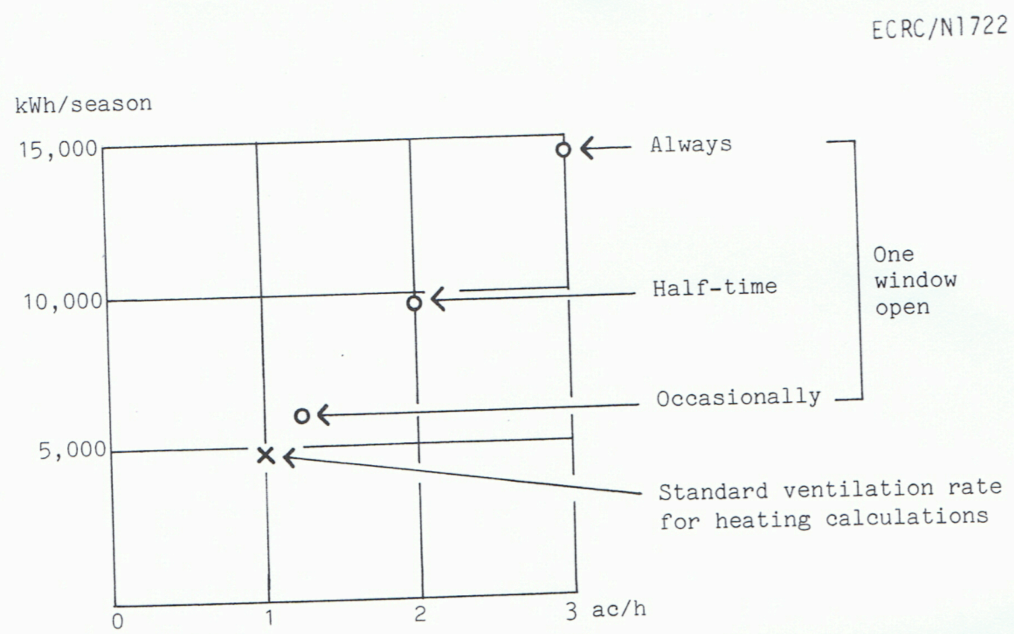


Fig. 7 Energy used in ventilating a normal house

In an average three bedroom masonry house the ventilation rate due to uncontrollable air leakage through the structure alone is likely to range between 0.3 and 0.7 ac/h. The same house, with some windows open, is quite likely to have 3 to 4 ac/h for some of the time, rising to 20 ac/h in extreme conditions.

Concern about air infiltration due to leakage is important because, as the thermal insulation is improved, heat energy loss resulting from ventilation tends to become the main source of heat loss. Many small gaps were found in the building structure, particularly in traditional masonry construction, that allowed air to pass freely in and out of the building.

Bricklayer, carpenter, plumber and electrician left holes and voids that all contributed to the later air infiltration routes. Bricklayers tend to skimp the filling of vertical joints with mortar, particularly those in inner leaf blockwork. Structural timbers dry and shrink. Characteristically, the gaps around the ends of floor joists bearing on the inner leaf of an external masonry wall could have an aggregate area of 40 cm^2 or more. Windows and doors were found to be poorly installed, with gaps in particular below cill and threshold, as were suspended timber ground floors.

Surface finishes were influential in improving or worstening airtightness. Wet plaster finishes seal the structure, whereas dry lining plasterboard contributes to air leakage. The building trades associated with air leakage are bricklaying, carpentry, plumbing, heating and electrician. Timber framed construction has particular attributes. Here, it is essential to install a complete vapour barrier to prevent moisture from the warm interior to migrate through the frame and form condensation on the cold side of the insulation. In turn, the vapour barrier provides air sealing as well. It follows that it is even more important in the case of timber frame to seal all service entries and flues passing through the outer structure. The services that pass into and out of housing are water, drainage, gas, electricity, oil, flues, ventilation and telephone. Television cables and chimneys need due attention, while cat flaps and postal flaps can also contribute to unwanted ventilation.

Reducing energy consumption also entails improving the efficiency of house services. There are two primary concerns; one is the need to give more importance to services in the design process, and not to leave them to be crammed in as an afterthought. The other is to make provision for their ready replacement, because building structure lasts far longer than most of the services within it. At present, gas boilers, for example, have an average life expectancy of thirteen years, after which they are replaced.

Ideally, services should be run only inside the thermally insulated outline of the building. This means, for example, that plumbing and ventilation ducting should not be located in the loft. This choice in turn influences the type of equipment to be installed, such as opting for a pressurised water system, with any header tank kept below the upper ceiling.

A Paper published in 1983 showed how ventilation ducting could be distributed within the first floor joist thickness. Unfortunately, manufacturers of domestic mechanical ventilation equipment mostly recommend locating their heat exchange and fan unit in the loft, plus its distribution ducting. Being outside the heated part of the house, the unit and ducting needs to be thermally insulated, ideally to the same standard as the house itself. An additional advertised feature of such systems is a heat exchanger by-pass, allowing cooling air to be circulated in summer. A well insulated loft gets hot in summer; so too will the ventilation equipment.

It has proved to be difficult to ensure that the duct penetrations of the upper ceiling are sealed. The difficulty of access, particularly where there are trussed rafters, makes periodic maintenance and cleaning difficult. It was soon realised that the loft hatch constituted a significant thermal weakness. This was because generally then it was an ill-fitting piece of particle board, with scant thermal insulation properties and with generous air leakage around it. The recommendations published in 1983 suggested solutions.

Developing practical building solutions to improve contemporary and future housing design and construction was of major concern, but the UK had millions of existing houses, and those certainly needed thermal improvement. A characteristic of this large stock of houses is the solid brick external wall. Improvement could only be made to it by applying insulation to the inside or the outside of the wall, or both. Internal insulation would be disruptive, and necessitate moving and refixing skirtings, window architraves, cupboards and electrical and plumbing fixtures. The insulation would need to be covered with a suitable finish, usually plasterboard. It would also need to impart fire resistance to flammable insulants. On the other hand external insulation, although more expensive, had attractive features. Its application would not be disruptive to the occupants and thicker insulation could be used. Fire resistance was still needed, but also with weather and impact resistance. An attractive feature for older local authority housing was that the external appearance would be changed. This is evident in the many high rise blocks, such as in Lancaster and Falkirk, that have been overclad with external insulation decorated in patterns in various colours.

A Paper was published by ECRC in1977, giving the background and practical details of systems of external thermal insulation. Since then a variety of such systems have been marketed, and a trade association formed.

In 1976 Capenhurst was approached by *Granada TV for help in deciding how to upgrade a severely dilapidated former coach house near Macclesfield. The producer's intention was to display the underlying practical aspects of not only bringing it back to lie, but to produce a low energy house. The resulting programme was so popular that a series of twelve programmes was eventually made, following in detail the whole design and build process. These programmes were well received by the public and were sold to TV stations on the Continent.

The coach house had solid brick walls, so a form of external thermal insulation was applied to them, carried by timber battens and counter battens. This was then clad with weatherboarding. A differing form of insulation was developed with Pilkington, using their glass fibre, but clad with wire mesh that was rendered. Later, development with Blue Circle Cement produced a glass fibre reinforced render on polystyrene board insulation. Later still, a house in Chester was rendered externally with a mixture of cement, sand and entrained small expanded polystyrene beads.

*(The Granada TV House for the Future is described in detail in another Chapter.)

Peter Boyce describes the work on lighting:-

Lighting Research at Capenhurst

Introduction

Lighting is an essential building service. Virtually all buildings are designed to have electric lighting even when they are primarily daylit because daylight fails, reliably, every day. During the 1970s and 1980s, the Merseyside region was a centre for research into lighting in Great Britain. For electric lighting, there was the Electricity Council Research Centre (ECRC) at Capenhurst on the Wirral while for daylighting, there was the Environmental Advisory Service at Pilkington Brothers in St Helens.

This note is focused on the work of the ECRC because that is where I worked. The ECRC was opened in 1966 as the fourth central laboratory of the nationalized electricity supply industry and the only one devoted to studying the utilization of electricity in all its variety. It was totally transformed by the privatization of the supply industry after which research on lighting ceased because there seemed little prospect of increasing load.

During its glory years in the 1970s and 1980s lighting research at the ECRC was undertaken to meet one of three aims:

- Developing new understanding
- Solving problems
- Evaluating new building types

Research can be a fruitful activity but unless it leads to changes, it is barren. Therefore, a common sequel to the research undertaken was a conscious attempt to convert the understanding gained into practical guidance by contributing to standards and guides relevant to lighting practice. CIBSE publications were certainly one area in which contributions were made but so were the publications of the British Standards Institution, the Health and Safety Executive, the Commission Internationale de l'Eclairage and, of course, the Electricity Council. These efforts were supported by the publication of many papers in the CIBSE journal, Lighting Research and Technology

Developing new understanding

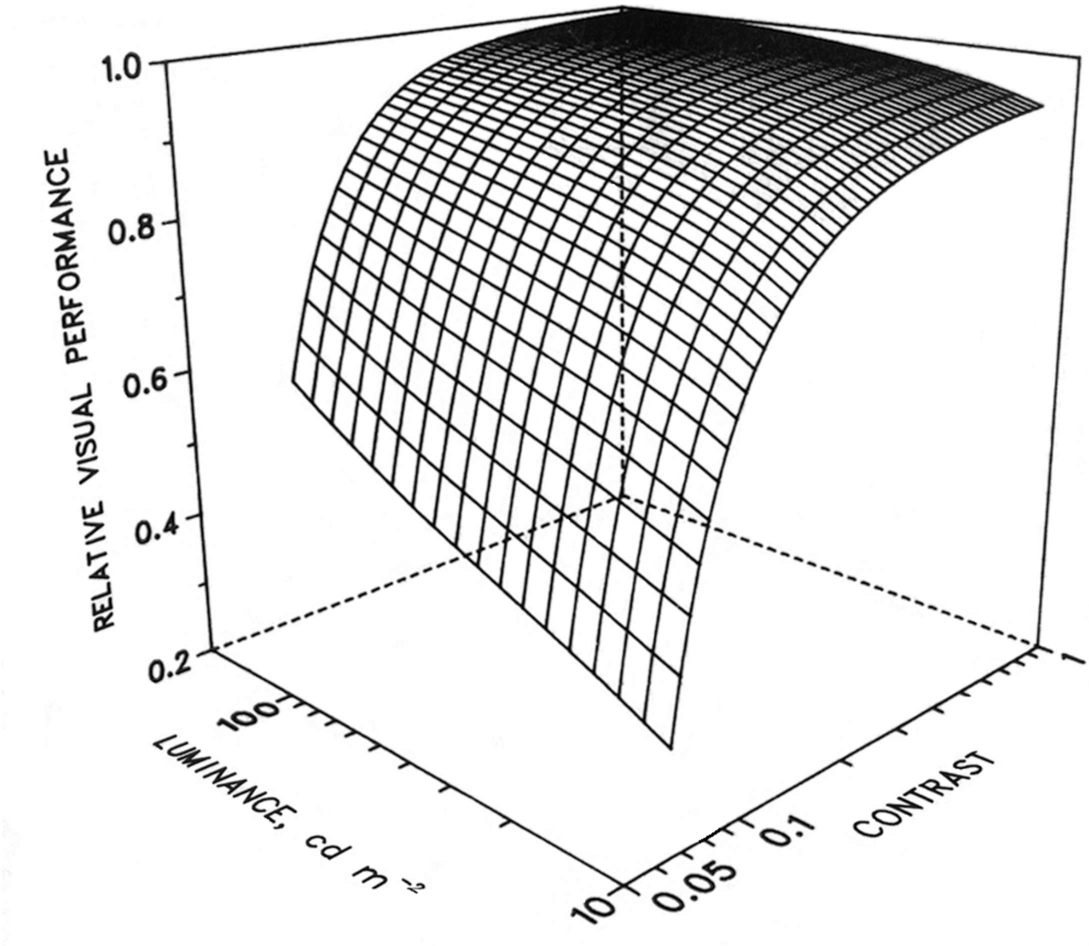
Research aimed at developing new understanding was the nearest the ECRC came to basic as opposed to applied research. The focus of this effort was the effect of lighting conditions on visual performance, a topic of interest because task performance was the claimed basis for the lighting standards contained in the CIBSE Code.

In the early 1960s, there was a clear divergence between the amounts of light considered necessary for good task performance in the USA and rest of the world, the illuminances in the USA being about twice those recommended for the same tasks elsewhere. Behind this divergence lay a fundamental difference in how to measure the effect of lighting on work. The studies undertaken of the relationship between light and work can be conveniently classified into two broad groups; abstract studies and real-task studies. The differences between these two groups are essentially those of face validity and generality.

The abstract studies used in the USA were characterized by the use of a task which was visually very simple and which no one had ever done for a living. The underlying aim of such studies was to achieve an understanding of how the performance of a visually simple task, with minimal cognitive and motor components, was influenced by lighting conditions. The outcome of these studies was usually a mathematical model that it was hoped could be used to predict the performance of tasks for different lighting conditions. Such studies have high generality but little face validity.

The real-task studies, typical of those undertaken in the rest of the world, involved taking a specific task that someone actually did and measuring the performance of the task under different lighting conditions, usually conditions that could be easily changed, such as the illuminance on the task, the spectral power distribution of the light source and the light distribution of the luminaires. These measurements were made either using a real task in the field or a simulated version of the task in a laboratory. Such studies have high face validity for the specific task, particularly when done in the field, but little generality. Real-task studies have served to demonstrate that changing lighting conditions can alter task performance and, for the task studied, this gives a quantitative basis for deciding on appropriate lighting recommendations.

Both approaches where used at the ECRC. An abstract task measuring the reaction time to the onset of a target differing in size and contrast seen against a background of different luminance isolated the relative impacts of lighting and task variables while minimizing the influence of the cognitive and motor components. This basic approach was later refined and expanded by Mark Rea and Mike Ouellette at the National Research Council, Canada into what is, today, the most widely accepted model of visual performance (see below).



Internationally accepted visual performance model

Real-task studies were undertaken to determine what was the minimum amount of light necessary for a person to find their way through a large furnished office under emergency lighting conditions. This work, carried out in the now demolished MANWEB headquarters building in Chester, used infra red beams to measure how fast people could move through the office and infrared video recording to observe the manner of their movement. These recordings were important in convincing standards bodies of the validity of the results and hence influenced emergency lighting standards in Great Britain and in Europe.

Solving new problems

Technology does not stand still for very long and when it changes, problems can arise. The office of today is strikingly different from that of the 70's. In the 70's, offices were paper-based. There were typing pools and communication was by letter. Today, nearly everyone has access to a computer system and communication is by e-mail. In the paper-based office, the primary surface to be viewed is horizontal and increasing the amount of light in the office makes any information on that surface more visible. In the computer-based office, the primary surface to be viewed is vertical and increasing the amount of light in the office makes the information displayed on the self-luminous screen less visible.

Therefore, the widespread introduction of computer-based technology into the office made a fundamental change in the requirements for lighting. To compound this problem, the visibility of the displays produced by early screen technology was very sensitive to the lighting conditions, mainly because of the use of dark background displays and specularly reflecting screens. Work at ECRC focused on identifying lighting systems that would minimize the amount of light falling on a computer screen when mounted on a desk, particularly light that produced a high brightness image of the luminaire (see below). The outcome was a Technical Memorandum for the CIBSE and another for the Commission Internationale de l'Eclairage both of which contributed to the development by the lighting industry of luminaires specifically for use with what were then called visual display units.

Reflection of luminaire in VDU screen

Another problem that grew in the 1970s was that of crime and terrorism. Security lighting was seen as a useful countermeasure but there was little guidance as to what form security lighting should take, particularly the amount of light required and the effect of different light spectra. Research at ECRC examined the effects of fence brightness on visibility through a fence, the aim being to maximize what a security guard could see while minimizing what a potential intruder could see. This was most easily achieved by minimizing the brightness of the fence on the guard's side while maximizing it on the would-be intruder's side. Another study examined the effects of different lighting conditions on people's ability to detect and recognize someone walking towards them. An illuminance of 10 lx on someone approaching was found to be sufficient to detect and recognize him or her. Data of this sort was combined with the expertise of the Electricity Council Marketing Department to produce a well – regarded guide to security lighting.

Evaluating new building types

The 1970s also saw a development in office architecture in which a maze of private offices was replaced by a large open space, the landscaped office. At the same time, the electricity supply industry was promoting another concept, integrated environmental design, in which the heat produced by lighting equipment in these well insulated buildings was removed before it entered the occupied space so as to reduce air conditioning load. A number of Area Boards built offices following this concept and ECRC was asked to carry out evaluations of the occupants' opinions, not just of the lighting but also of the thermal and air quality conditions. It is always good for researchers to get out of the laboratory and into the real world if they want to understand what really matters to people. The nature of the work, the pay, the other people in the office, the difficulty of the journey to work and the state of the toilets where all more important than the environment. To some extent this was because the environment in these buildings was broadly satisfactory but of all the aspects of the environment examined, lighting was the most successful although more daylight and a better view out would have been appreciated. Thermal conditions were the most common cause of complaint.

It was also found that the airflow through a luminaire used to collect the heat had to be designed with care if dirt deposition was to be avoided. It was not enough to filter the incoming air to the building because there was a plenty of dirt generated inside the building. Such findings did not lead to a dramatic changes or guidance documents but they did add to the sum of knowledge on how to handle the environment in buildings, knowledge that is needed today when integrated environmental design has taken on a slightly different meaning, namely designing to enhance sustainability.

Impact

Lighting practice is largely governed by the technology available and the prevailing economic situation but within these constraints, it is also influenced by guidance on what constitutes good lighting. As explained above, individual studies or groups of studies undertaken at ECRC contributed to the publication of advice for specific lighting applications by authoritative bodies. But there was also a more general impact. Until the publication of European (CEN) Standards relevant to lighting the most widely used set of lighting recommendations in Great Britain was the Code published by the Illuminating Engineering Society and, after amalgamation with the IHVE, by the CIBSE. The tables of illuminances recommended for different types of work in the Code acted as de facto standards, the legal requirements in Britain being, with few exceptions, confined to worthy statements such as that the lighting should be sufficient and suitable. The knowledge and understanding of the effects of lighting on task performance and comfort gained through work at the ECRC was put to good use through extensive input to the 1973 and 1984 Codes.

It is therefore very clear that for a period of two decades, lighting practice in Great Britain was influenced by work done on Merseyside.

The assistance of Tony Mould and Dr Peter Boyce in the preparation of this Chapter is gratefully acknowledged