APPLICATIONS IN COMMERCIAL BUILDINGS

Report by Professor M J Holmes

Introduction

This theme area is intended to investigate recent advances in the analysis and design of systems intended to be used in the commercial building sector. In most cases that is taken to mean office buildings and while most of the papers prepared for this session do indeed address that area it is gratifying to discover that other types of building our now being studied, in particular the specific needs of supermarkets and auditoria are addressed. As might be expected many of the papers stress the application of simulation and are even bold enough to look towards validation. However as usual that issue is, in the main, ignored.

Simulation studies in general carried out to predict:

Energy consumption;
Temperatures during hot periods;
Optimum plant performance;

and many of the papers presented here do not disappoint in meeting these aspirations, however there is a hope for the new in that the issue of simulation to assist commissioning is now introduced.

When looking at the application of simulation there are a number of questions that come to mind:

Why is it being done?	If this question cannot be answered we should not simulate.
Is it because it is the latest thing?	Is this a good reason?
What will the simulation tell us?	
Was it cost effective?	
Has it improved the design?	
Are costs reduced?	
Is energy saved?	
Is the environment improved?	

I do not intend to ask these questions directly of any of the papers but ask that the reader has them in mind.

The papers may be dived into three groups:

Air distribution design;
The quality of the internal environment;
Building and system simulation.

Some papers cover more than one area, in which case I have placed those papers where I believe them to be more relevant.

1. AIR DISTRIBUTION DESIGN

For the present purpose I take air distribution to cover supply and extract systems and what is done within the conditioned space. Four papers fit into this category:

> Brief Discussion on Fire-proofing and Fume Extracting System Design for Heating, Ventilating and Air-Conditioning of High Buildings. Pan Y.
> Duct Loops and VAV Modelling and Control. Khoo I. Levermore G. Letherman K.
> The Effect of Room Thermal Environment on the Performance of Cooled Beams. Livtchak A. Horttanainen P. Jankov G. Artemov V.
> Experimental Study of airflow in Underground Space of Metro System with a Constant Tracer-Gas Injection Techniques. Lix. Lix. Zhu Y.

The paper by Pan presents a review of various methods used to control smoke in high rise buildings. This includes listing the methods used a 22 hotel buildings in China. It is perhaps unusual to find a paper which looks at simple ways to do essential things, however it is important to remember that much engineering design is carried out using methods based upon hand calculations. The techniques discussed are intended to prevent smoke moving around the building although the main theme of the paper is to suggest that the HVAC system can be used to control smoke. This is not well established although there are obvious language barriers in the interpretation of this paper. What is perhaps regrettable is that no attempt is made to provide a critical assessment of the different methods presented and so little aid is offered to the designer.
The second paper (Khoo et al) related to the ductwork system provides more help to the designer, using simulation to investigate the performance of duct loop VA. system. That is where a ring main is used instead of a linear air distribution system.

The value of this paper lies not in detailed simulation but that it shows that the advantage that might be obtained by considering alternative approaches to a conventional design. Furthermore it is demonstrated that the traditional methods need to be questioned, for example the optimum location of the static pressure sensor needs careful consideration. It is my experience that engineers do not use the power of simulation to assess the performance of the system; this paper goes some way to demonstrating the values derived from a proper understanding of how the distribution system works.

The simulation, or often visualisation, of airflow is now the province of the computational fluid dynamics and two papers within this section make use of that tool in very different circumstances. The first of these (Livtchak et al) looks at the performance of active and passive chilled beams. The concern is to demonstrate that the performance of the device is affected by the environment in which it is used and so questions the validity of standardised performance tests. This point is well taken but of course, not unique to chilled beams, however, it should be the objective of performance tests to provide reference data so that the engineer can predict performance over a range of conditions. The value of the paper is that it should make the designer consider more than standard test results. It should also alert those designing such tests of the need to provide information that can be used to predict under non-standard conditions.

The preceding paper made no attempt to demonstrate the validity of the computational method, unlike the work of Xiaofeng et al who have carried out both experimental and numerical studies on airflow within a subway station. The main concern here is to determine how much of the air 'pushed' by a train in the tunnel mixes with the air on the platforms. This quantity is needed to calculate both cooling loads and air quality. The only practical way to measure mixing is by means of tracer gas techniques. This is quite difficult to do in large spaces and the authors were only able to determine local concentrations and air velocities. These are used to validate the numerical model employed to predict dual mixing rates. The validation evidence is impressive. This paper should give confidence to the simulation, however, it is important to recognise that unlike when CFD is used to predict conditions in rooms the boundary conditions were very well defined. In particular the flow pattern did not depend upon very small differences in temperatures and pressure. It is also probable that the turbulence model would not have much effect on the predictions. It is however a pleasure to find a paper that contains experimental data, it is also unfortunate that the data are not presented in a way that others can make use of them.

2. QUALITY OF THE INTERNAL ENVIRONMENT.

The internal environment may be assessed in terms of thermal comfort, the level of unpleasant but not essentially dangerous gasses and harmful pollutants. The papers featured in this group are remarkable in that the cover nearly all issues associated with the quality of the indoor climate. They range from a theoretical assessment of methods that can be use to predict pollutant levels to very practical ways in which to achieve a good environment. The titles and authors are:

Insuring Thermal Comfort in Climatised Office Buildings. Erdosi I. Kajtar L. Banhidil L..
Limitations of Models for Characterising Indoor Particle Concentrations from Cigarette Smoking in an Office Environment. Bohanon H R. Cole S K.
Results from Field-Testing of an IR-Controlled Ventilation System in an Occupied Office Building. Ducarme D. Wouters P. L'Heureux D.
Maintaining IAQ by Proper Operation of HVAC Systems. Salzauler J.

At the simplest level the quality of the environment is judged by the temperature within a space. A single design figures is all that is often used to do this. However it is well known that comfort is affected by many factors and the current ISO standard makes user of Fanger's comfort equation to define these. simplifications in the form of weighted temperatures such as the dry resultant recommended by CIBSE are possible but there are practitioners who question the need for more than air dry bulb. One way to convince people to recognise the complexities of the thermal environment is by means of case studies, this has been done by Erodsi et al. The paper is short and to the point, it presents the results of measurements in an office environment and compares these with a survey of the occupants. The data recorded and the survey apply to areas near to and distant from a cold window. The effect of cold radiation is demonstrated in that people nearer to the window felt cold. This is said to justify the Fanger approach and to indicate the need to use the operative temperature as the design condition. While the authors provide comfort indicators from both measurements and survey little attempt is made to show direct comparisons. If that had been done this short paper would have added some weight to discussions on the validity of PPD and PMV values.
Predictions of a different kind are considered by Bohanon and Cole. Their interest lies in the

area of suspended particulate matter in room air characterised by cigarette smoke. To many, because the general restrictions on smoking, this could be seen as an area of limited interest. The study has a more general validity because the contaminant production from the smoke not only enters the room air but is also deposited upon the room surfaces. Many other contaminants have a similar behaviour. The researchers have identified 9 different models for the prediction of the concentration of contaminants. These are compared with measurements. The agreement was to say the least poor. Reasons given were that the models were too simplistic not recognising deposition or imperfect mixing within the space. The authors then develop their own model (not based on CFD) and using measured contaminant generation and deposition rates attempt to use that to predict the level of respirable suspended particles. The results were an improvement of the other models but did not manage to correctly reproduce experimental data. One reason for this is that simplistic models cannot represent the spacial distribution of particulates. The area is one that is still ripe for research and indeed much is being carried out at the Imperial College of Science and Technology in the UK using modified CFD codes. The researchers (Professor David Goddard and Dr Myriam Byrne) are having some success. The lesson here is that it is sometimes necessary to use complex methods, the trick is to know when.

The remaining two papers are both far more practical in nature and compliment one another. While Decarme et al seek to prove by demonstration that an occupant density based control system will maintain an acceptable level of air quality Salzauler provides sound guidance on how to ensure that quality is achieved. The system investigated by Decarme makes use of a infrared detector to activate the air supply system to the room. The idea is that no air is supplied if the room is empty, once people enter a flow valve opens and air is introduced thus air quality is maintained and energy consumption reduced. In addition to the control concept the valve used contains filters. This is a rather special system and so generalisation of the study may be limited. This is of course always the danger of case studies. The authors demonstrate that such a system is practicable but for it to be effective there must be very little duct leakage because the system relies on a complete shut of the air to the unoccupied spaces. Should there be significant leaks the energy savings will be compromised, obvious but so are many things associated with air quality and energy consumption, for example the need for proper maintenance as stressed in the paper by Salzauler.

The paper by Salzauler is aimed at the design engineer and contains little new however it does represent a good state of the art review of design methods. It is also recognised that most problems in buildings are caused by poor maintenance, it would appear however that insufficient research has been carried out to define what is required. The issue of calculation of contaminant levels from both furnishings and other sources is also raised in the paper but only at the very simple level used by many design engineers, perhaps there is a need to introduce the more complex considerations of Bohanon and Cole into the design process - or to take a more practical approach and select materials that do not cause problems. The calculation of appropriate air supply quantities to maintain a healthy environment and the way to assess that environment are still subject to discussion. This paper will at assist in that debate but will help the engineer to move in the right direction.

3. BUILDING AND SYSTEM SIMULATION

The bulk of the papers in this seminar fall this category, however, system and building simulation covers many areas and so the papers have been further divided into the following groups:

Retail premises:

Influent Parameters on Energy Consumptions in Frozen Area of Large Supermarkets. Orphelin M. Marcho D. Bech S.
Effects of Indoor Relative Humidity on Refrigerated Display Case Performance. Howell R H. Rosario L. Bulla A.

Storage systems:

Cost-Effective Design of Thermal Energy Storage Components for HVAC Plants
Fernandes J F. Maldonado E.
The Optimum Analysis on Air-Conditioning System with Partial Cool Thermal Storage by PCM
He L. Ding L.

Modelling:

Design and Simulation of the Closed Water Loop Heat Pump. Sauer H J. Rao G.
Simulation Analysis of Energy Requirements in HVAC Systems Used in Commercial and Community Buildings. Baranowski A. Wasacz M.
Optimisation of Chilled Water Systems Based on Part Load Cooling Tower Performance
Howell R.H. Summers C.D.
Simulation-based Analysis of the Overheating Risk in an Auditorium Building. Andre Ph. Nicolas J.

Simulation related commissioning issues:

Experimental and Analytical Evaluation of VA. Air-Conditioning System in an Office Building Wang S. Burnet J.
Commissioning of a Centralised Cooling Plant. Bourdouxe J P. Bilas F. Georges B Hu H. Jennes V. Lebrun J. Pimenta J M.

3.1 Retail premises

The main objective of the two papers is similar - to assess the energy used by systems and frozen food display cabinets in supermarkets - the adopted are quite different. Orphelin et al have attempted an approach that models the coupling of the display cases to the store air-conditioning system by analysis the convective floor between the two elements. Howell et al makes use of factors derived from previous work to represent the effect of changes in store relative humidity on the energy consumption of the storage cabinets. This method has the advantage of simplicity and should allow rapid assessments of performance. It would appear that the effect of the storage cabinet on the store air-conditioning system is not considered. This may be justified in that the authors suggest that the display cases account for about 70% of the energy use of the store. If this is true it is necessary to question the need for the detailed modelling used by Orphelin. The importance of the modelling of the case/store interaction is that it highlights the need to seriously consider the effect of convective flows between zones when simulating systems. A simple example in conventional buildings might be the coupling between perimeter and core zones in open plan office buildings.

The conclusions reached by the two are different, in one case it is suggested that there is an optimum store relative humidity of 45% (Orphelin) which results in overall minimum energy consumption. Alternatively Howell appears to show the lower the relative humidity the lower the energy consumption. Could this be an effect of ignoring coupling?

3.2 Storage systems

The two papers stress the importance of cost in the application of thermal storage by means of phase change materials. This is not new. The contribution to the field are in the area of design with He Ligun taking a relatively simple approach that could be done using spread sheets. There are however, many constants that need to be determined. It is not clear how this can be done. It is however, important to understand that perhaps it is not always necessary to make detailed simulations. This issue is also addressed in the paper by Fernandes and Maldonado which examines a number of design techniques. Of significant interest to designers is how much detail is necessary to make s proper assessment of the performance of a storage system. To do this they have looked at design day methods through to detailed simulations using the DOE2 program. The results indicate that detailed simulations are the only way to obtain a proper understanding of the system. These simulations must include the control strategy. Simple ‘rule of thumb’ sizing methods such as the reduction of the peak installed cooling capacity to 60% of the design value apparently have some credibility - but how was the 60% set?

It is encouraging to find validation data however these seem to show that simulation program predicts general trends (periods of high demand, for example) but otherwise the detail appears to be coincidental. It would be interesting to see how much can be left out of the simulation before it looses the ability to predict trends.

3.3 Modelling

The papers assigned to this section range from studies of the best way to achieve quality system models (Howell and Summers) to a demonstration of how simulation can be used to optimise the performance of a building (Andre and Nicolas). The other two papers are interested in appropriate methods. This is a very important issue, which is also raised in the previous section (Fernandes and Maldonado) because much time can be wasted using detailed simulation tools when only a simple analysis is required.

Baranowski and Wasacz starts with the hypothesis that while a detailed simulation model may be capable of providing an excellent assessment of the performance of a building and it’s systems the process is expensive and prone to error due to the user. Simplified models may be appropriate if what is required is a pointer to the right direction. To do this models that represent the main thermodynamic processes are compared with detailed component model using the program TRNSYS. They conclude that such models are appropriate for the indication of trends. It would however appear that the detailed model is required for a proper determination of loads. This is very similar to the conclusion reached by Fernando and Maldonado. We still do not know how detailed a simulation needs to be.

The paper by Sauer and Rao appears to address this issue. The objective is to look at the way simulation can be used to design a water loop heat pump system. Unfortunately the paper lapses into a demonstration of how simulation can be used to predict performance. The give comfort to the simulator in that it is demonstrated that because system performance varies with location it is essential to model. The authors conclude that the program used was a useful tool. There is no evidence provided to suggest that this was the best way to approach The problem.

Howell and Summers also provide a paper dedicated to the application of system simulation, however in this case there is more on how to do it and how valid the results are. The intention is to use a model of a cooling tower and chiller to optimise the performance of a chilled water system. The method adopted is the time honoured approach of fitting manufacturers data to theoretical performance models. This is probably the most sensible way to tackle simulation, test data is never likely to be 100% valid for the range of the simulation (an issue also raised by Livtchek et al), and simple numerical extrapolation is often dubious. While the paper may be for a particular example the approach can be generalised.

The final paper in this group (Andre and Nicolas) tackles a major design issue, how to reduce overheating without mechanical cooling. It is important to realise the building exists and the current performance is known. This is not an abstract study. Simulations are first used in an attempt to predict the current performance of the space and then to assess design options. As seen before trends are reproduced but not the details. In particular space temperatures are underestimated. Thus simulation can be expected to point the way but not provide accurate data on the performance after retrofit. The paper provides a very good demonstration for how to use simulation in the design context. The conclusion - to provide cooling - is probably sensible in the light of the under predicted temperatures.

What would we do if there were no measurements?

3.4 Commissioning

Commissioning is a new area for simulation to address and while it could be that the paper of Wang and Burnet might belong to the air distribution section it is felt more appropriate to include it here. The reason is that the objective of their study is to use simulation to justify the installation of a new control system and presumably to tune that system. The air distribution system in question is a standard VAV system controlled by a conventional static pressure sensor located in the 'rule of thumb' position. The objective is to look at savings that might be obtained by means of a control system that knows how much flow is required. To do this they have measured the pressure flow characteristics of dampers fans etc and then simulated the current and proposed system. The results indicate energy savings in the region of 20%. In addition to energy savings the authors are to be congratulated in that they also have investigated ways to improve air quality. There is one area perhaps that should have been addressed (and maybe it has and is not clear) the efficiency of the fan control system and the effect of inaccuracies in sensors. We need to ask that if the practical considerations are ignored will the conclusions still be valid. There is also room for a discussion on how to take the practical operation into account. The paper of Bourdouxhe et al which relates simulation to the commissioning of a real system may help.

One problem facing the commissioning engineer is often lack of data, in this case there appear to be no flow meters fitted to the cooling plant. Simulation of performance under specific assumptions and comparison with other measurements is used to find out how the plant is working. This paper therefore looks at a very practical use of simulation. The building chosen is located in Brussels and has a system that makes use of ice storage. The methodology for the simulation is fairly standard in that an established program (TRNSYS) was used, however because the simulation was of an existing plant it was important to ensure that the numerical models represented reality. To do this the authors make use of curve fits to manufactures' data and some theoretical models, in particular that for an ice storage tank. The paper concentrates upon the model of the storage system and in particular validation of that model. In this respect it is unfortunate - and no fault of the researchers - that the only data available was that recorded by the Building Management System (BMS). BMS data is not reliable, the authors demonstrate this and I have personal experience of significant errors. Thus it is not possible to prove the validity of the simulations. It is not possible to stress too strongly that data from BMS systems is unreliable and that it is essential that those studying the behaviour of buildings and systems instal their own equipment. (As an aside - if the data are of little use for validation - of what use are they?). The inability of the authors to prove that the model is validated does not retract from the value of the paper which is I am sure will become a reference source to those attempting to simulate the performance of existing buildings.

4. CONCLUSIONS

Simulation of commercial buildings is happening. The models used can reproduce the main characteristics of system and building performance but perhaps not the detail.

There is no agreement on how detailed a simulation needs to be, studies in this area will be invaluable to ensure the cost effective use of simulation.

Manufacturers must provide data to allow the modeller to extrapolate the performance of plant and so improve design.

It is necessary to question the validity of data recorded by Building Management Systems. There is evidence of errors, is this due to poor commissioning, algorithms or low quality sensors? In general these systems offer the researcher the only way to check simulations, if the data is flawed how do we proceed?

Finally there is a long way to go.

> Researchers please look to Validation.
> Engineers please use the tools but be sceptical but also careful in selecting the input data.

5. THE PAPERS

P 7*: Experimental and Analytical Evaluation of VAV Air-Conditioning System in an Office Building Wang S. Burnet J. (HONG KONG)

P52*: Design and Simulation of the Closed Water Loop Heat Pump
Sauer H J. Rao G. (USA)

P67*: Brief Discussion on Fire-proofing and Fume Extracting System Design for Heating, Ventilating and Air-Conditioning of High Buildings. Pan Y. (P.R. CHINA)
P 93*: Cost-Effective Design of Thermal Energy Storage Components for HVAC Plants
Fernandes J F. Maldonado E. (PORTUGAL)

P 180*: Insuring Thermal Comfort in Climatised Office Buildings
Erdosi I. Kajtar L. Bandhidi L. (HUNGARY)

P 194*: Commissioning of Air-conditioning System
Hu H. Georges B. Lebrun J. (BELGIUM)

P 206*: Influent Parameters on Energy Consumptions in Frozen Area of Large Supermarkets
Orphelin M. Marchio D. Bech S. (FRANCE)

P 231*: The Effect of Room Thermal Environment on the Performance of Cooled Beams
Livtchak A. Horttanainen P. Jankov G. Artemov V. (FINLAND)

P 254*: The Optimum Analysis on Air-Conditioning System with Partial Cool Thermal Storage by PCM
He L. Ding L. (P.R. CHINA)

P 263*: Maintaining IAQ by Proper Operation of HVAC Systems
Salzsauler J. (CANADA)

P 270*: Simulation Analysis of Energy Requirements in HVAC Systems Used in Commercial and Community Buildings. Baranowski A. Wasacz M. (POLAND)

P 275*: Effects of Indoor Relative Humidity on Refrigerated Display Case Performance
Howell R H. Rosaro L. Bula A J. (U.S.A.)

P 276*: Optimisation of Chilled Water Systems Based on Part Load Cooling Tower Performance
Howell R.H. Summers C.D. (U.S.A)

P 278*: Experimental Study of Airflow in Underground Space of Metro System with a Constant Tracer-Gas Injection Techniques.
Li X. Li X. Zhu Y. (P.R. CHINA)

P 292*: Commissioning of a Centralised Cooling Plant.

Bourdouxe J P. Bilas F. Georges B Hu H. Jennes V. Lebrun J.
Pimenta J M. (BELGIUM)

P 325*: Duct Loops and VAV Modelling and Control
Khoo I. Levermore G. Letherman K. (UNITED KINGDOM)

P 328*: Simulation-based analysis of the Overheating Risk in an Audtorium Building.
Andre Ph. Nicolas J. (BELGIUM)

P 331*: Limitations of Models for Characterising Indoor Particle Concentrations from Cigarette Smoking in an Office Environment.
Bohanon H R. Cole S K. (U.S.A.)

P 333*: Results from Field-Testing of an IR-Controlled Ventilation System in an Occupied Office Building
Ducarme D. Wouters P. L'Heureaux D. (BELGIUM)