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2ND EUROPEAN CONFERENCE ON ARCHITECTURE 4–8 December 1989 PARIS, FRANCE Sponsored by Commission of the European Communities

# CONDENSATION TARGETER

by

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## Abstract

This paper describes a design tool, 'Condensation Targeter', for assessing condensation risk in dwellings and the effect of remedial measures thereon. The BREDEM energy model is augmented by a moisture model to determine mean internal relative humidity (MIRH). This measure of condensation risk is calculated for two zones in a dwelling from mean internal temperatures, moisture generation and ventilation rates. Primary input data relate to occupancy (fuel expenditure and moisture production) and dwelling characteristics (thermal and ventilation). MIRH results are presented as a function of space heating input for an example dwelling with remedial measures applied (insulation and extract fans). The constraints imposed by household income and the implications for condensation risk are discussed. Comparisons between model predictions and monitored results are discussed as is the sensitivity of predictions to the accuracy of input data.

## 1 Introduction

Mould growth occurs in 10 to 20% of housing in the UK and several other European countries. Considerable funds are now being allocated to the refurbishment of these buildings. At present some of this money is misdirected, as mistakes are made in the design and installation of anti-condensation measures. One reason for error is the lack of adequate design tools for making decisions on the best means of remedying condensation and mould growth in particular dwellings.

Research at many institutions around the world is now leading to a better understanding of the mechanisms causing condensation and mould growth. However, few comprehensive design tools are available which contain the most up-to-date thinking on remedial measure design. This paper outlines one way of addressing these problems through a combined energy and condensation model. The BREDEM energy model /1/ has been enhanced by incorporating Loudon's condensation model /2/. The final objective of this work has been to produce a computer package for use by building designers when refurbishing housing. This calculates the risk of condensation within dwellings using two main parameter inputs; dwelling characteristics and type of occupant (e.g. pensioners, unemployed families, single persons etc.) as illustrated in Figure 1. Remedial measures (e.g. draught stripping, central heating, etc.) can then be compared for their effect on condensation risk.

Condensation risk is here taken to mean both the risk of surface condensation and the risk of mould growth due to high humidity conditions on a surface without liquid water present.

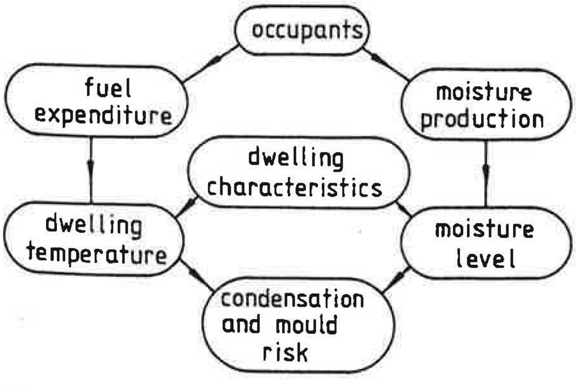

**Figure 1** Model for condensation risk prediction

## 2 Model Selection

A condensation risk prediction model which can analyse the effects of changes to building design, moisture control and fuel expenditure requires components which determine the temperature and moisture content of the air inside the dwelling. In practice two integrated models are required; a thermal model and a moisture model.

Current thermal models which deal with energy consumption and internal temperatures in buildings range in complexity from those based on steady-state heat loss for hand calculation to large dynamic simulation models requiring mainframe computers. The latter are all complex and are unsuitable for use as design tools. However, several simple but sophisticated models have been developed to predict annual energy consumption. The Building Research Establishment (BRE) have designed the core of such a model, called BREDEM /1/, which the present authors considered to be the best vehicle for a condensation risk model. A major advantage is the availability of a very 'user friendly' implementation of version BREDEM-5, which is commercially available as the 'Energy Auditor' computer package/3/. The latter is already widely used as a design tool on refurbishment projects.

BREDEM is a two-zone modified degree-day model which accounts for casual and solar gains, and the efficiency and responsiveness of a variety of heating systems. 'Energy Auditor' was specifically designed for examining the energy savings associated with improvements to the building fabric and heating system of existing buildings. The accuracy of 'Energy Auditor' has been tested and reported by Henderson and Shorrock /4/.

Much less work has been done on moisture and condensation models than on thermal models, since energy has been far more of a national issue than condensation during the past two decades. The most generally accepted model for prediction of surface condensation and mould risk is that due to Loudon /2/. This model uses just two steady-state equations to determine mean internal relative humidity (MIRH); one for energy balance and one for moisture balance in a dwelling or zone. Condensation risk is considered to be unacceptably high if the MIRH in the space exceeds 70%. This work has helped to improve understanding of the interactions between the many factors involved in condensation; it has recently been introduced into a draft revision of BS 5250 /5/ as a simple design tool. The present authors have therefore chosen to incorporate a moisture balance equation into BREDEM.

## 3 Interaction of thermal and moisture models

The dwelling is treated as two separate zones as set out in BREDEM: the 'living area' taken as Zone 1 and the 'rest of the house' as Zone 2. The kitchen may be allocated to Zone 1 or Zone 2 depending on the layout of the particular dwelling. The thermal model calculates the mean internal temperature (MIT) of each zone, whole house ventilation rate and energy consumption over the heating season. The moisture model calculates mean internal vapour pressure for given moisture generation and ventilation rates in each zone. The division of the dwelling into two zones is an improvement on whole-house assessment since it allows modelling of different modes of heating and moisture production in different parts of the home. The structure of the model is shown schematically in Figure 2. For a detailed description of the model see reference 6.

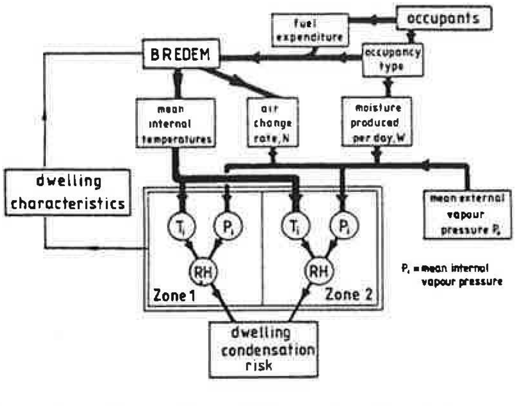

**Figure 2** Integration of thermal and moisture models

## 4 Assessment of condensation risk

### *4.1 Influence of dwelling characteristics*

An assessment of condensation risk must be made from the mean internal relative humidity (MIRH) of the two zones in the dwelling. Within a real occupied dwelling the risk of condensation or mould growth will vary widely due to spatial and temporal effects. BS 5250 asserts that the condensation risk will be unacceptably high when MIRH exceeds 70%. The validity of this limit is open to question, however, it does seek to account for differences between conditions in the bulk air of a room and those on the inside of external surfaces and for the fact that mould may grow where surface RH is less than 100%. Measurements in environmental chambers have shown that mould grows on wall covering materials if the relative humidity is greater than 80% for a period of several days /7/.

In this paper a value of MIRH=70% has been taken as critical with regard to condensation risk. However, this will underestimate the condensation risk in certain dwellings where the surface temperatures are low so that the surface RHs are greater than 80% with a MIRH lower than 70%. For example, external walls with U-values greater than 1.2 $Wm^{-2}K^{-1}$ or thermal bridges in well insulated walls may a have low surface temperatures which will result in mould growth at a MIRH of less than 70% /8/.

### *4.2 Influence of occupant income*

Condensation is critically dependent on dwelling MIT which relates to occupant income through space heating input. For low income groups the amount of money and thus fuel available for space heating is limited. Hence, dwelling MITs decrease with decreasing income as confirmed by a number of studies /9/10/. Field study /10/ data has shown that decreasing income leads to a progressive fall in the temperature of Zone 2, while that in Zone 1 remains relatively constant. This implies that people with limited resources maintain a comfortable temperature in their living room while either reducing the heated area in the rest of the dwelling or reducing the temperature at which the latter is maintained.

BREDEM is uniquely structured to model this practice. A number of BREDEM calculations can be performed for different areas of heating in Zone 2 and decreasing demand temperature in Zone 1.

## 5 Use of model

The integrated thermal and moisture models have been applied to a specific building to illustrate the operation of the condensation prediction method. To facilitate comparison of results with those of earlier studies, a mid-terrace two-storey house with the same construction as the example house used by Loudon /2/ was analysed, see reference 6 for constructional and thermal details.

Two generic types of remedial measure are available for combating condensation in dwelling: those which increase mean internal temperature and those designed to reduce internal vapour pressure. An example of insulation (i.e. a measure which increases the MIT) is shown in Figure 3. Taking the original mid-terrace house to be occupied by two adults and three children producing 8.5 kg $day^{-1}$ of moisture, MIRH of 70% in Zone 2 is maintained for a total space heating load of approximately 52 GJ $y^{-1}$. The space heating required to maintain the same conditions in the insulated house is reduced by more than half to 25 GJ $y^{-1}$.

Remedial measures which effectively reduce the input of moisture to the dwelling include the installation of kitchen and bathroom extract fans. Figure 4 illustrates the effect of this in the case of the unmodified house occupied by a five-person family. It is assumed that extract fans are fitted in the bathroom and kitchen which remove 80% of the moisture produced by cooking and bathing. The effect of the fan is to reduce the MIRH in Zone 2 by approximately 10% for a given space heating load. The corresponding decrease in the space heating fuel requirement to avoid condensation is 40%.

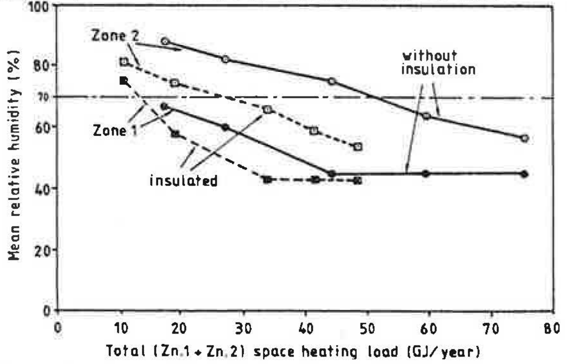

**Figure 3** Zone MIRH for standard (U value - wall 1.7 $W/m^2K$, roof 1.4 $W/m^2K$)and insulated (U value - wall 0.6 $W/m^2K$, roof 0.35 $W/m^2K$) versions of two-storey mid-terrace house (occupied by a five-person family)

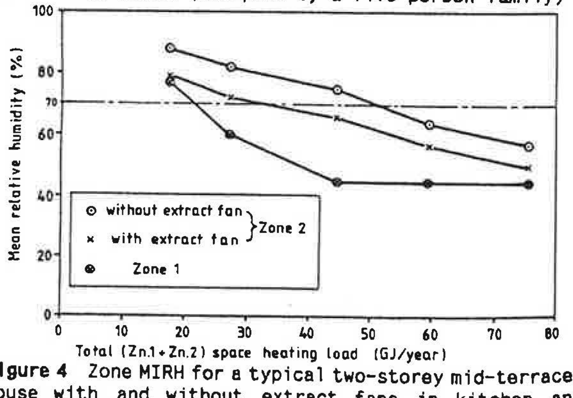

**Figure 4** Zone MIRH for a typical two-storey mid-terraced house with and without extract fans in kitchen and bathroom (five-person family)

A more complex measure like draught stripping affects both MIT and vapour pressure. For a relatively leaky house with a mean ACR of 2.0 $h^{-1}$ occupants must supply 52 GJ $y^{-1}$ total space heating to avoid condensation in Zone 2. If draught stripping were applied and the ACR reduced to 0.5 $h^{-1}$, MITs are significantly increased by about 4°C for the same energy input. However, condensation risk is increased, not reduced, because of the accompanying rise in internal vapour pressure. In fact to avoid the condensation risk in Zone 2 heat input must be increased by about 27%.

It is important that designers are aware of how little households have to spend on fuel and how this relates to condensation risk. Consider a five-person family living in the house described above. If the two adults were unemployed the household income from supplementary benefit payments would only be £113 per week. On average they would only spend £9.29 per week or £483 per year of this on fuel /6/. The total cost of hot water heating, cooking, standing charges, lights and appliances as calculated by 'Energy Auditor' is £380 per year, leaving the hypothetical family with £103 per year to spend on space heating. This is equivalent to a heating load of 28.6 GJ $y^{-1}$ (with gas central heating). Reference to Figure 3 shows that this family could not afford to heat their home sufficiently to avoid condensation without the installation of remedial measures such as wall insulation.

## 6 Discussion

The tool outlined in this paper enables designers to assess the condensation risk which might result from dwelling refurbishment. It enables quantitative comparison of how this risk may be reduced by various remedial measures, e.g. installation of insulation, efficient heating systems and mechanical ventilation. The approach highlights the necessity for dwellings to be appropriate to the needs of occupants; dwelling insulation and heating systems must allow comfort conditions and space heating fuel bills which the occupants can afford. The result of insufficient heating is that people endure reduced temperatures which may lead to mould growth, condensation and building fabric decay. The use of this model will help to identify failures in design (e.g. inappropriate draught-stripping) and so avoid costly maintenance of remedies.

Developments of this condensation risk model has been led by demand. The imperative of providing an easy-to-use design tool has resulted in a simplified approach which has several shortcomings and unvalidated assumptions. Work is in progress to appraise the assumptions and to validate the model against real data and experience. Two main areas of concern are the use of average MIRH and ventilation analysis.

The assessment of condensation risk by using temperature and moisture generation averaged over time and space within a dwelling may not be entirely appropriate. Time averaged MIRH may be sufficiently low to regard a dwelling as theoretically free from condensation, yet condensation may occur at troughs of temperature and at peaks of moisture generation. In addition, thermal and moisture capacity of the building fabric is neglected in the above model but intermittent heating and occupancy may result in condensation. Similarly, spatial averaging does not account for high condensation risk in specific rooms of a dwelling. Transient affects can not be fully accounted for until the response of mould growth to transient conditions is understood, this work is being carried out the Building Research Establishment.

Partitioning of the dwelling into zones, as effected by BREDEM, may not give sufficient resolution for predicting condensation risk. However, analysis of air and moisture exchange between the two zones and to outside is complex. In the above model it has been assumed that the two zones are decoupled for moisture migration. Allowing for inter-zone moisture transfer can alter the Zone MIRH by up to 5%. Improving this part of the model will depend on the development of an appropriate ventilation model requiring relatively simple dwelling and occupant data. Similarly, the efficiency of extract fans in reducing internal vapour pressure (under both humidistat and occupant control regimes) needs elucidation.

The predictions obtained from any model are only as good as the input data. The above model has therefore been tested to see how sensitive the predictions are to the accuracy of the input data. The model is most sensitive to the fabric loss where a 1% change in fabric loss can result in a 1% change in predicted RH.

Preliminary comparisons between modelled results and measurements in several dwellings has shown good agreement when predicting the average dwelling MIRH (i.e. modelled MIRH within 5% of measured). The Zonal predictions however have been in error by up to 8% suggesting that the model does not adequately account for moisture movement between zones or the allocation of moisture production to each zone.

The condensation risk model discussed in this paper, now called 'Condensation Targeter', has been integrated into a commercial computer package called 'Energy Targeter'/11/. Energy Targeter calculates the total energy cost, and total cost of remedial measures, as well as assessing the risk of surface and interstitial condensation. The integration of condensation assessment into a general refurbishment tool has meant that building designers who would not normally consider the quality of the indoor environment are made aware of condensation risks. Energy Targeter has therefore proved a useful vehicle for carrying research results into practice.

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Acknowledgement

This work was carried out while the authors were employed by the Polytechnic of Central London