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NATURAL VENTILATION: GOOD PRACTICE IN THE UK -
A Pre-Design Check List to Minimise Summertime Overheating Risk

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In the UK's temperate maritime climate, the need to air-condition a non-domestic building outside city centres should be the exception rather than the rule. Nevertheless, the potential clients for new or refurbished buildings, whether tenants or owner occupiers, are concerned about whether a non-air-conditioned building can deliver comfortable and productive working conditions, particularly in summertime. To convince client decision makers (facilities managers, property directors, etc.) and their professional advisers (architects and engineers), that natural ventilation can deliver both low energy performance and high occupant satisfaction, a document has been written that draws together the most compelling evidence: the example of successful precedents. This paper elaborates the technical basis for a pre-design check list provided in the document as a preliminary means to quantify summertime overheating risk, and so to try to steer designs for natural ventilation in the right direction.

INTRODUCTION

Adequate ventilation of buildings to provide fresh air and to remove airborne pollutants and excess internal heat gains is essential for the well-being of occupants. In many commercial buildings, ventilation and cooling is provided via mechanical systems at considerable financial and environmental cost, with potential health problems if systems are not properly cleaned and maintained. Often occupants actually prefer natural ventilation, which they perceive is the only ventilation solution which can give them a "breath of fresh air", whilst owners of naturally ventilated buildings benefit from lower energy and maintenance running costs and the credit for a more environmentally benign building.

A document [1] has been written in which the benefits and features of natural ventilation are demonstrated by examples from recent buildings in a variety of situations: greenfield, urban and suburban newbuild; urban and suburban refurbishment. It is not intended to be a detailed natural ventilation design guide; there is already a considerable number of these to choose from [2,3,4]. The guide aims to give confidence to clients and design teams who are considering the use of natural ventilation, by demonstrating through feedback on their effectiveness and performance in use, that there are many successful precedents to follow.

The document also provides a pre-design check list of the main factors which affect summertime temperatures in non-air-conditioned buildings. This paper explains the technical basis for the check list and shows that it represents a preliminary means to quantify overheating risk at the earliest stages of design and so to steer designs in a direction of lower risk.

DEVELOPMENT OF A CHECK LIST PRE-DESIGN TOOL

The concept of a rule of thumb check list to test whether natural ventilation could provide acceptable thermal comfort in summer was first suggested by Twinn [5]. The approach was adopted with minor amendments by both BRE [4] and then CIBSE [2] in subsequent design guides. However, the table provided in these documents is restricted in the flexibility it allows designers to trade off one factor against another, and it was considered that a more comprehensive method could be developed. The objective was to create a reliable, flexible and simple design aid, comprising a list of the main factors affecting summertime temperatures, which quantified:

1. the effect of a particular factor having different values; and
2. the resultant effect of different combinations of the various factors

The proposed check list is shown in Table 1. The general principle is to offer between 0 and 4 credits (the lower the risk of overheating, the greater the number of credits) for each of 9 factors which affect summertime temperatures: fresh air provision, exposed mass, night purging, lighting gain, glazing ratio, orientation, shading, equipment gain and occupant density.

To try to ensure that for every factor each additional credit equates to a similar reduction in the risk of overheating, the effect of each feature has been calibrated using the NiteCool software tool developed by BRE and Oscar Faber [6]. NiteCool requires a user to assign values for the above factors and then predicts a peak comfort temperature for a given zone of a building during a design week of weather data (external temperature). The aim of the calibration of the check list was to try to make the effect of a single credit on the peak temperature equivalent to a change of about 5 W/m^2 in heat gains. For those factors actually measured in W/m^2 this was clearly straightforward: 1 credit equated directly to 5 W/m^2. For other factors, the calibration was indirect, using the observation that each extra 5 W/m^2 of heat gains typically caused an increase in the peak temperature of 0.5 to 1.5°C, see Figure 1, and so 1 credit was equated to a change in predicted peak temperature of around 1°C.

Factor	**Poor/Not applicable**	**Minimal**	**Average**	**Good**	**Excellent**
Credit		•	••	•••	••••
Fresh air provision: EITHER open plan	1 ach	Sealed windows with mechanical ventilation providing about 2 ach	Single sided, twin opening window elements, plan depth <= 2.5 H	Cross ventilation to chimney or atrium, twin opening window elements, plan depth <= 5 H (Or mech vent to provide about 5 ach)	Cross ventilation to outside, multiple opening window elements, plan depth <= 5 H
Fresh air provision: OR cellular offices	1 ach	Sealed windows with mechanical ventilation providing about 2 ach	▨	Single sided, single opening window element, plan depth <= 2.5 H (Or mech vent to provide about 5 ach)	Single sided, twin opening window elements plan depth <= 2.5 H
Exposed Mass	Raised floor and suspended ceiling	Screeded floor OR partial suspended ceiling	Raised floor AND exposed ceiling	Exposed ceiling slab and solid floor	Exposed ceiling slab with ventilated cores
Night Purge	None	Manually openable windows or vents	Automatically controlled windows or vents	▨	▨
Lighting Gain	High installed lighting load (>20 W/m^2) AND Minimal daylighting	Above average lighting load (15 to 20 W/ m^2) AND Minimal daylighting	Typical lighting load (10 to 15 W/ m^2) AND Minimal daylighting	Good practice lighting load (5 to 10 W/ m^2) OR Good daylighting AND Good control	Low installed lighting load (< 5 W/ m^2) OR Very good daylighting AND Good control
Glazing Ratio	> 70 %	50% - 70%	35% - 50%	25% - 35%	< 25%
Orientation	West	▨	South	East	North
Shading	None	Internal blinds	▨	Mid-pane blinds	External louvres or blinds in outer cavity of triple glazing
Equipment Gain	> 20 W/ m^2	15 to 20 W/ m^2	10 to 15 W/ m^2	5 to 10 W/ m^2	< 5 W/ m^2
Occupant Density	< 5 m^2 /person	5 to 6.5 m^2 /person	6.5 to 10 m^2 /person	10 to 20 m^2 /person	> 20 m^2 /person

Table 1 Factors affecting summertime temperature

In addition to the quantifiable parameters included in the checklist, there are other more subjective factors which also affect thermal comfort in summer:

1. direct contact with openable windows
2. ceiling height
3. occupant clothing
4. the presence of ceiling fans

These items are not taken into account by NiteCool and have instead been allotted credits according to their anticipated benefit, as follows:

1. Contact with windows which open provides occupants with a subjective feeling of well being and a greater tolerance of higher temperatures. Based on an assumption that an increase of the order of 1°C would be accepted, the checklist offers one extra credit for windows on an external facade (rather than, say, onto an atrium).
2. A high ceiling enables hotter vitiated air to stratify above head height. The checklist offers an extra credit for a floor to ceiling height of at least 2.8m and two extra credits for a height of at least 3.2m.
3. The dress code which occupants follow can affect their perceived comfort. The checklist assumes a typical clothing level for an office environment in summer (0.75clo). From [7] there is a 3 °C change in comfort temperature for a difference between lightly (0.5clo) and formally (1.0clo) clothed individuals if all else remains constant. Based on this finding, one credit is deducted if occupants are unable to remove their jacket, but one credit is added if they are able to wear informal clothes.
4. Ceiling fans are assumed to increase air movement from 0.2 m/s to 1 m/s. For sedentary activity levels and standard clothing levels this air movement can increase the comfort temperature by up to 2 °C [7]. Provision of ceiling fans is rewarded by an extra credit.

EVALUATION OF CHECK LIST

To provide confidence in the validity of the check list, a two stage evaluation is necessary: first, an inter-model comparison to verify that the check list gives similar results to the NiteCool software and secondly empirical validation in which the check list is applied to case study buildings and the results compared with the responses from occupant surveys.

Inter-Model Comparison

The main inputs to NiteCool are day and night ventilation rates, amount of exposed mass, orientation, facade glazing ratio, shading coefficient and internal heat gains. Table 2 shows how the possible input values to NiteCool would be classified according to the check list in Table 1.

A series of NiteCool runs were undertaken to assess 135 reasonably realistic combinations of the inputs in Table 2; the results are shown in Figure 2 as a graph of the predicted peak temperature for each run plotted against the total number of credits. The important feature of this graph is the relative lack of scatter ($R^2 > 0.90$), which indicates, as hoped for, that designs achieving a given credit score by different means should have similar risks of summertime overheating.

NiteCool input / *Check list factor*	Check list classification				
	Poor	Minimal	Average	Good	Excellent
Credits	0	1	2	3	4
Day vent (ach)/*fresh air provision*	1	2		5	
Night vent (ach)/*night purge*	0	2	5		
Thermal mass/*exposed mass*	Light / Medium		Heavy		
Orientation/*Orientation*	West		South	East	North
Glazing ratio (%)/*glazing ratio*	80	60	40	30	20
Shading (%)/*shading*	0	30		50	80
Internal gains (W/m^2)/*lighting, equipment gain, occupant density*	70	55	40	25	10

Table 2 NiteCool inputs classified according to the check list design aid

The absolute value of the peak temperature is a function of both the design and the external temperature which in this study was set to peak at 27°C. To serve as a useful design aid, designers need to know what is an acceptable level of overheating risk. This would need to be discussed carefully with the client for each individual project. It is suggested that for a typical office, under the above outside temperature conditions, designers should be aiming for a peak temperature in the range 28 to 30°C, which corresponds to a target total of 21 to 24 credits.

This compares with the maximum total for a real design of around 36 credits, including the 4 possible extra credits for factors outside the main check list.

Empirical Validation

In the document [1], the check list has been applied to 5 case studies for which survey data is available for occupant satisfaction with summertime temperatures. The 5 buildings achieve credit totals of 20, 20, 24, 25 and 30. This exercise was a useful test of the applicability of the check list to actual designs. As yet the small sample size and narrow range of credit totals make it inappropriate to investigate the correlation between occupant satisfaction and credit total.

STRUCTURE OF THE DOCUMENT

The pre-design check list described in the previous sections is included within a document which contains 3 main parts, as follows.

First there is an overview of the need for ventilation, how natural ventilation fits into the continuum of options for the provision of ventilation and the major issues to be addressed in a successful natural ventilation design. This section incorporates the pre-design check list.

Second there is a section which consists of a 2 page spread for each of 5 main building case studies. Each one contains one page which describes the client's brief, the design concept and the natural ventilation features and modes of operation and a second page which summarises the building's performance in use, including data on comfort, energy and capital cost, and explains the advantages and pitfalls of features used.

Finally there is a section describing key areas in natural ventilation design based on the experience in and lessons to be learnt from existing buildings. Each main point or recommendation is explained using an illustration from recently completed projects. The section is sub-divided into 5 main parts:

1. Window design. Issues considered include winter and summer operation, integration with daylight and solar shading, refurbishment, external noise and pollution and security.
2. Other natural ventilation devices. This includes solar stacks and chimneys, wind towers, courtyards and atria.
3. Exposed thermal mass. This considers integration with lighting, acoustics and night cooling.
4. Control. This covers the various means to control natural ventilation, including the full range of combinations of manual and automatic controls.
5. Verification. This describes the wide range of tools available to aid the design team's analysis at all stages of design, using both analytic and physical models.

CONCLUSIONS

1. A check list design aid is proposed to provide an early quantitative indication of summertime overheating risk in a non-air-conditioned building. A target score that designers should aim at when using the check list is suggested.
2. The check list has been validated against a dynamic computer model and data is being collected from real buildings to provide empirical validation.
3. The paper describes a document aimed at clients and design teams who are considering the use of natural ventilation. The document explains good practice based on the example of successful precedents.

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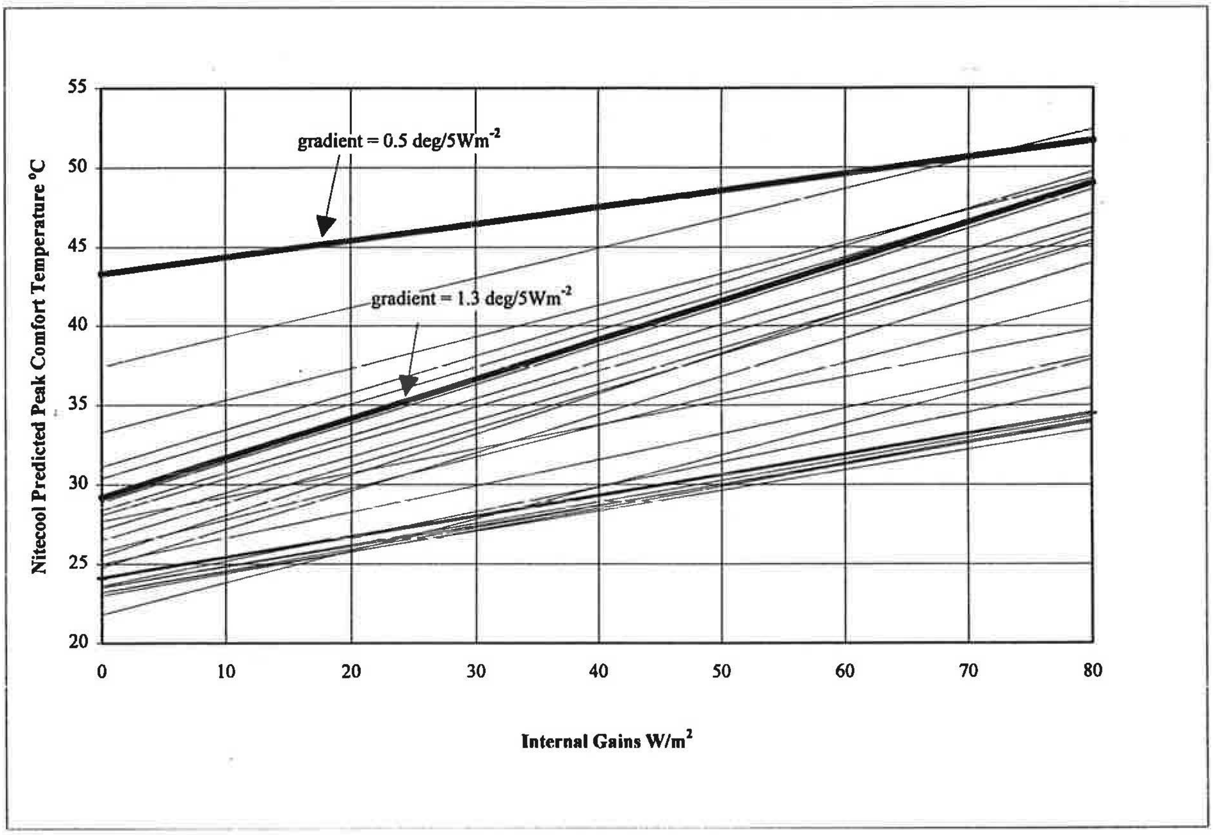

Figure 1 - Variation in the rate of change of predicted peak internal temperature with internal gains for each combination of factors that were modelled. Each line represents a case with a specific set of fixed values for each factor, except for internal heat gains which are varied from 0 to 80 W/m^2.

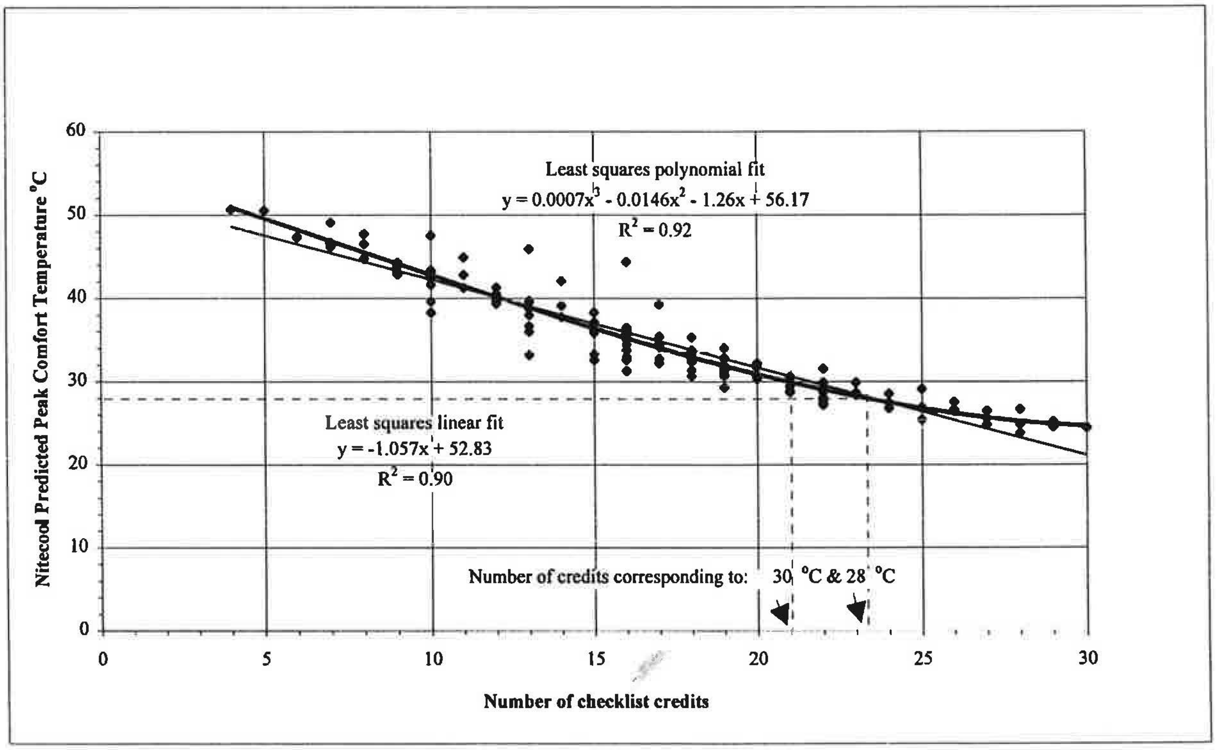

Figure 2 - Variation of predicted peak internal temperature with total number of credits