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Report 12

Comparison of Alternative Criteria for Assessing Overheating in Buildings

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March 1992

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1. Introduction

As part of their work in the International Energy Agency (IEA) Annex 21 the Subtask B group are trying to document methodologies for assessing the risk of overheating in buildings. These methodologies lay down the analysis procedure to be followed when using a particular thermal model. Methodology documents (PAMDOCS) have been developed by various countries and each uses a different criterion for assessing overheating and each one is based on a different computer program.

The purpose of this piece of work is as follows:

(a) to assess the consequences of using different criteria for classifying overheating, and

(b) to assess the influence on the predicted risk of overheating of using different computer programs.

The analysis will be conducted using data which was already generated as part of the UK ETSU Applicability Study 1 project. In this project great care was taken to avoid any mismatch between the data fed into the various computer programs, therefore any differences in the predictions will be due either to the different algorithms used by the programs, or due to the different overheating criteria which are being used.

2. Overheating Criteria

Five different criteria for defining overheating have been analysed, the definition of each of these was taken from a report produced by Halcrow Gilbert Associates for the UK Department of Energy[1]. Each of the methods is based on analysing the results of hour by hour simulation programs which have been run for a whole year. No criteria based on design-day analyses or which are devised for simple programs such as BREADMIT have been studied.

Criterion 1 - is used within the UK Passive Solar Programme (PSP) and states that temperatures over 27°C should not occur for more than 3% of the working hours in a year. In this study the temperature was taken to be the dry resultant temperature and it was assumed that the working hours were from 9.00 am to 5.00 pm every day (that includes weekends and holidays i.e. 365 days per year).

Criterion 2 - is used in Holland and indicates that there should be no more than 5% of working hours with a temperature of greater than 25°C for 60% relative humidity, and no more than 1% of working hours with a temperature greater than 28°C. Again the temperature was assumed to be the dry-resultant temperature and the same definition of working hours was adopted. The condition relating to relative humidity was ignored for the purposes of this study so we simply analysed dry-resultant temperatures above 25°C and dry resultant temperatures above 28°C.

Criterion 3 - is used in Switzerland in the Zurich Canton. This criterion is one of three which may be used to demonstrate that air conditioning is

necessary within a building. In this criterion the product of hours x temperature in excess of a defined level is used to assess overheating. The defined level is taken to be 24°C up to an ambient temperature of 12°C, and 28°C when the ambient temperature exceeds 20°C. The defined level varies linearly between 24 and 28°C as the ambient temperature varies between 12 and 20°C. The point here is that occupants are likely to tolerate higher maximum room temperatures as the ambient temperature itself becomes higher. The criterion is that 30 kelvin hours per year must not be exceeded, and if it is then air conditioning is permitted within the building.

Criterion 4 - is that used by UK, Design Note 17 (DN17), for the design of school buildings in the UK. In this criterion the number of days in the year for which the indoor temperature exceeds 27°C is determined. If during normal working over the school year the resultant temperature is in excess of 27°C or for over 10 days during summer, it states that this is a reasonable predictive risk. It is not clear exactly what this means, for the purposes of this analysis it has been taken that 10 days is the limit allowable.

Criterion 5 - used in Applicability Study 1 (AS1) is simply the number of hours in the year for which the temperature exceeds 27°C. There was no limit ever placed on this parameter, it was simply used as an indication of overheating.

3. Programs Used

In this study, 3 programs were used, ESP, HTB2 and SERIRES. All three programs are finite difference programs which have been well used within the UK and have been subject to various validation exercises. In particular ESP and SERIRES have been used within IEA 21 Subtask B and also IEA 21 Subtask C. To test the above criteria, the predictions of dry resultant temperature from ESP and HTB2 were used. SERIRES however produces a temperature which is a mix of air and radiant temperature. This we call the enclosure temperature and it was against this temperature that the above criteria was tested.

4. Building Analysed

The internal temperatures in the Linford Passive Solar House (in the UK) were predicted using each of the programs. The house was modelled as 5 zones with one of them being the living/dining room. This room had a large area of south facing glazing, and it is this room in which the internal temperatures will be analysed. The walls of the house were thermally heavyweight and well insulated to produce a U-value of 0.3. The building was heated with a low pressure hot water system controlled by individual thermostats sensing pure air temperature. It was assumed that the house was occupied by a family of 4 people who were in the house for the entire day. These people controlled the rate of ventilation by opening the windows if the air temperature exceeded 25°C. The effect of this was to increase the ventilation rate from one air-change per hour to 5 air-changes per hour. For the purposes of this study, the house was subject to Kew weather conditions (London). Hourly air, mean-radiant, and

hence resultant temperatures, were predicted for every hour of every day in the year for all three programs. It was then possible to analyse these values using each of the above criteria.

Additionally, to determine how the criteria responded to differences in the area of glazing, the building was analysed with four different areas of window in the south facing living/dining room. A small area of glazing representing 28% of the actual area of the buildings as designed, a medium area (63% of the final design area), a large area (100% - the actual designed area, and a huge area (135% of the designed area). We would therefore expect that under summer conditions the likelihood of overheating will increase as the area of glazing increases from that represented by the small glazed area through to that represented by the huge glazed area.

5. Results

5.1 Presentation of Results

The results are given in tables 1 to 4. These contain the method, a brief statement about the criteria, and the limit which is applied to the criteria. The results for each program ESP (E) HTB2 (H) and SERIRES (S) are then given as the number (i.e. working hours, degree-hours or days depending on the criterion) and the percentage (i.e. of working hours, degree-hours, days etc.) for which the limit temperatures are exceeded. Symbols are then given (either N for no or Y for yes) to indicate whether according to the particular criterion overheating has indeed occurred. Statistics are then given which represent the range from the lowest predictor to the highest predictor, the mean prediction for the three programs, and variation as a percentage of the mean. For example, on Table 2, using the PSP criterion which relates to the number of hours above 27°C, ESP calculated 83 working hours, HTB2 24 and SERIRES 12. These are respectively 2.8, 0.8 and 0.4% of the total working hours and therefore they are all less than the 3% which is the PSP criterion, and therefore no overheating occurs. The variation between the SERIRES and ESP results was 71 working hours, the mean result was 40 working hours, and the variation as a percentage was therefore 178% - quite large (Table 2).

Glancing at the tables it can be seen that in Table 1 none of the criteria predict that overheating will occur. In Table 2 however, overheating may or may not be deemed to have occurred depending on the program or criterion which is used. As we move to Tables 3 and 4, representing large and huge areas of south glazing respectively, we can see that all the methods predict that overheating has occurred.

5.2 Effect of Program

Firstly, the differences between the three programs when using a given criterion will be studied (Fig. 1 to Fig. 5). It can be seen (Fig. 1) that using Criterion 1 (PSP), ESP predicts that overheating will begin to occur at much smaller window areas than predicted by the other programs. In particular, ESP indicates that the overheating limit of 3% of working

hours will be exceeded with a window area of about 62% of the design area, whereas HTB2 and SERIRES indicate that it will be exceeded when the window area is as large as 80 to 85% of the design area. Looking now at Figures 2, 3, 4 and 5, it can be seen that in all of them ESP predicts that overheating will begin to occur far sooner than either of the other programs. In other words, irrespective of the criterion used, because ESP predicts higher internal temperatures it also predicts a higher likelihood of overheating for any given window area and, in this exercise, that overheating limits will be exceeded at smaller window areas.

It has not been possible to undertake a sensitivity study to determine the aspects of the computer programs which are the main cause of these divergent results. However analysis conducted during the AS1 project, suggest that they are unlikely to be due to either the choice of internal surface heat transfer coefficients or the window algorithms adopted by the programs. (These two algorithms had minimal impact on the prediction of internal summertime temperatures in the buildings). It is possible that the external solar radiation models or the external surface heat transfer coefficients, particularly at window surfaces, are the cause of the results. It has not been possible to analyse these propositions at this stage.

5.3 Effect of Criterion

Although the influence of programs on predictions is important, of more interest within Subtask B of IEA 21, is the effect which adopting different criteria may have on the assessment of a particular building. Although some work has been done to assess this within subtask B, because different programs are being used by different people, it is difficult to disaggregate the effects of the program and the user from the effects of the criteria themselves. By using the data from AS1, it is possible to disaggregate the effects of the criteria from the other issues. To do this it is necessary to plot the results from the criteria on a common set of axis. Therefore, the actual predicted values were expressed as a percentage of the limit used with the criteria, e.g. looking at Fig. 1, and the predictions of ESP with the PSP criterion, it can be seen that ESP predicted 2.8% of the working hours in the year exceeded 27°C (for a window area of 63% of the design area). Now, the limiting value is 3%, the 2.8 therefore represents 93% of the criterion limit. Turning to the Dutch criterion (Fig. 2) using the 28°C limit, 0.6% of working hours exceeded the limit and the criterion is 1%, therefore the 0.6 represents 60% of the criterion limit.

Figure 6 shows these results for all the criteria for ESP plotted on this basis, the fraction of overheating (as a percentage) on the Y axis and the window area along the X axis. It can be seen that the Dutch 25°C limit predicts that the overheating limit will be exceeded with a window area of only 28%. The Dutch 28°C limit however, suggests that the window area could be as large as 68% before overheating occurs. These represent the extremes of the predicted values. The results for the other criteria are however also very variable. The Swiss criterion suggests that overheating will occur with a window area of 30%, the DIN17 limit suggests that 42% is allowable, whereas the passive solar program limit suggests that the

Method	PSP			Dutch			Swiss			DN17			AS1		
Criterion	No. Wrk.hrs>27°C			No. Wrk.hrs>25°C or > 28°C			No. Degree-hrs. (T_{amb} dependent)			No. Days>27°C			No. Hrs>27°C		
Limit	3%			5% or 1%			30			10			-		
Program	E	H	S	E	H	S	E	H	S	E	H	S	E	H	S
Number	0	0	0	113/0	44/0	18/0	3	0	0	1	0	0	2	0	0
%	0	0	0	4.8 / 0	1.5 / 0	0.6 / 0									
Overheating?	N	N	N	N	N	N	N	N	N	N	N	N	?	?	?
Variation	0			95 / 0			3			1			2		
Mean	0			58 / 0			1			0.3			0.7		
% Variation	-			164% / -			-			-			-		
Comments	Total no. of working hours (9-5) = 2920, weekends and holidays not considered			Criterion is based on high humidity (60%), this is not considered here. New method is based on PMV			Degree-hours base varies from 24°C at $T_{amb} \leq 12$°C to 28°C at $T_{amb} \geq$ 20°C			Additional Criterion is 23°C ± 4°C					

Table 1: Overheating Assessment based on Dry Resultant Temperature using AS1 Linford Results (Kew. Small South Glazing Area)

Method	PSP			Dutch			Swiss			DN17			AS1		
Criterion	No. Wrk.hrs>27°C			No. Wrk.hrs>25°C or > 28°C			No. Degree-hrs. (T_{amb} dependent)			No. Days>27°C			No. Hrs>27°C		
Limit	3%			5% or 1%			30			10			-		
Program	E	H	S	E	H	S	E	H	S	E	H	S	E	H	S
Number	83	24	12	707 / 17	391 / 4	169 / 2	233	51	24	23	10	6	110	36	19
%	2.8	0.8	0.4	24.2/0.6	13.4/0.1	5.8/0.1									
Overheating?	N	N	N	Y	Y	Y	Y	Y	N	Y	N	N	?	?	?
Variation	71			538 / 15			209			17			91		
Mean	40			422 / 8			103			13			55		
% Variation	178%			128% / 188%			202%			131%			166%		

Table 2: Overheating Assessment based on Dry Resultant Temperature using AS1 Linford Results (Kew, Medium South Glazing Area)

window area could go up to 62%. So, with the program ESP, the allowable window area varies considerably depending on the criterion which is used. Turning to the results from the other two programs HTB2 (Fig. 7) and SERIRES (Fig. 8) the similar spread in the results can be seen. In all these cases the Dutch 25°C limit allows the smallest window area, and either the passive solar program or Dutch 28°C limit allows the largest window area allowable.

Clearly then, even if the same program is used, for the same location, the window area which will be allowed could vary by a factor of between 2 and 3 depending on whether the Dutch, Swiss or the UK passive solar program and DN17 criterion are used.

6. Conclusions

1. Using the results from Applicability Study 1 it has been possible to disaggregate the variability in overheating assessment which is due to programs, from that which is due to the user or the criterion on which the assessment is based. The risk of overheating differs quite markedly depending on the criterion which is used, in particular, for the dwelling which was studied, the allowable window area could vary by a factor between 2 and 3 depending on which criterion is adopted.

2. The computer programs ESP, HTB2 and SERIRES differ quite markedly in their individual predictions of the likelihood of overheating. Analysis in AS1 suggest that these differences are not due to differences in the algorithms for modelling internal surface heat transfer coefficients and windows. It is possible that they are due to the modelling of external surface heat transfer coefficients and the solar radiation distribution assumed by the sky models.

References

[1]Halcrow Gilbert Assoc. Ltd. (1991) Thermal Comfort, Performance Assessment Methodology Development Project, Warrant 6 Development of Performance Assessment Issues, Final Report to UK Department of Energy, 29-pp.

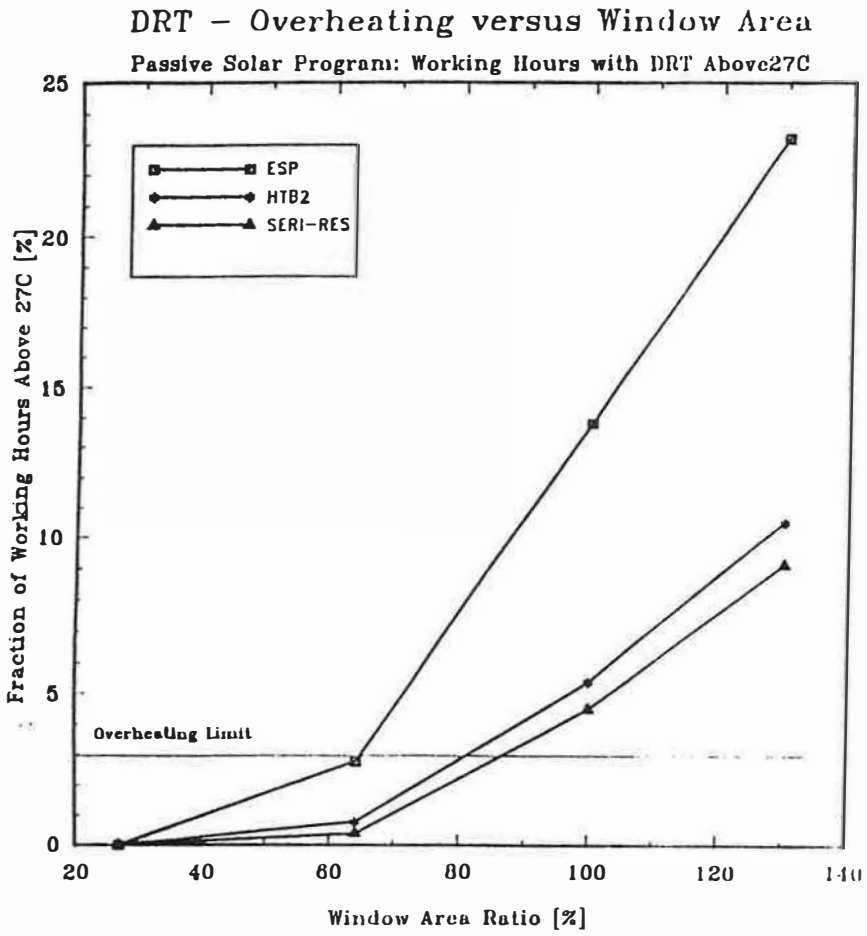

Figure 1: Overheating predictions using Criterion 1 - PSP

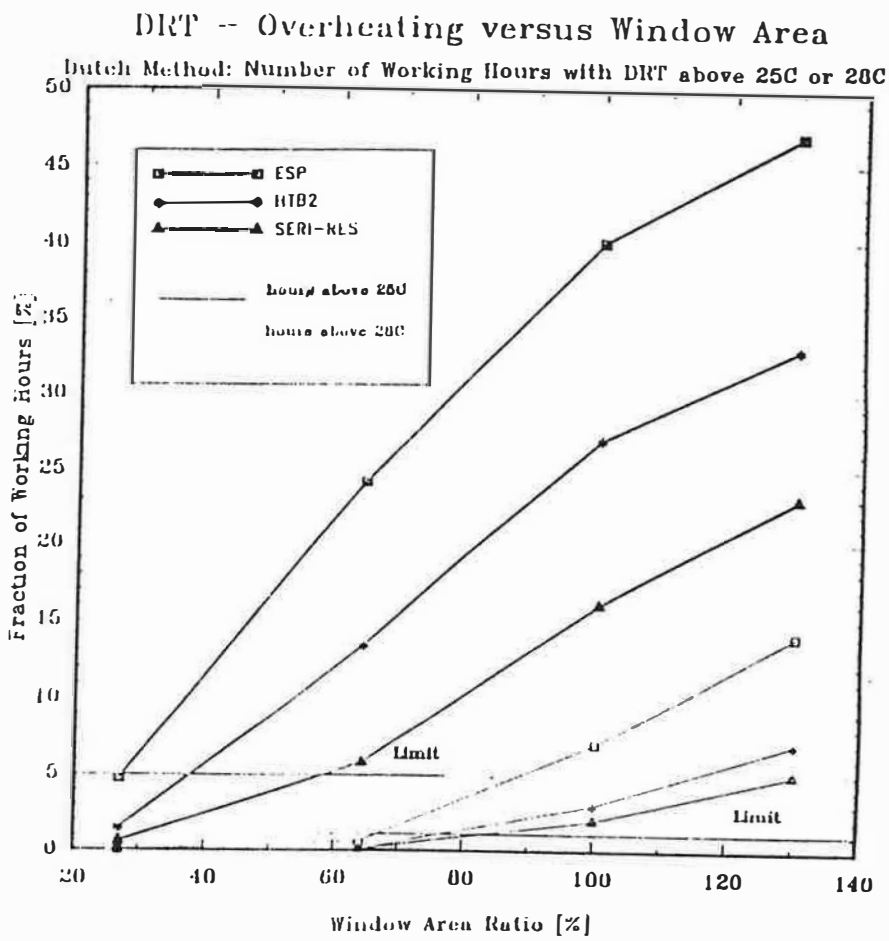

Figure 2: Overheating predictions using Criterion 2 - Dutch

Method	PSP			Dutch			Swiss			DN17			AS1		
Criterion	No. Wrk.hrs>27°C			No. Wrk.hrs>25°C or > 28°C			No. Degree-hrs. (T_{amb} dependent)			No. Days>27°C			No. Hrs>27°C		
Limit	3%			5% or 1%			30			10			-		
Program	E	H	S	E	H	S	E	H	S	E	H	S	E	H	S
Number	404	158	131	1156/191	781/89	456/54	1407	432	229	89	46	34	505	217	167
%	13.8	5.4	4.5	40 / 7	27 / 3	16 / 2									
Overheating?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	?	?
Variation	273			700 / 137			1178			55			333		
Mean	231			798 / 111			589			56			236		
% Variation	118%			88% / 123%			171%			102%			214%		
Comments	Total no. of working hours (9-5) = 2920, weekends and holidays not considered			Criterion is based on high humidity (60%), this is not considered here. New method is based on PMV			Degree-hours base varies from 24°C at $T_{amb} \leq 12°C$ to 28°C at $T_{amb} \geq$ 20°C			Additional Criterion is 23°C = 4°C					

Table 3: Overheating Assessment based on Dry Resultant Temperature using AS1 Linford Results (Kew Base-case, Large South Glazing Area)

Method	PSP			Dutch			Swiss			DN17			AS1		
Criterion	No. Wrk.hrs>27°C			No. Wrk.hrs>25°C or > 28°C			No. Degree-hrs. (T_{amb} dependent)			No. Days>27°C			No. Hrs>27°C		
Limit	3%			5% or 1%			30			10			-		
Program	E	H	S	E	H	S	E	H	S	E	H	S	E	H	S
Number	677	306	266	1363/412	973/140	674/154	2860	1085	693	133	80	65	873	416	334
%	23.2	10.5	9.1	47/14	33/7	23/5									
Overheating?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	?	?
Variation	411			689 / 258			2167			68			539		
Mean	316			1003 / 252			1528			93			541		
% Variation	130%			69% / 102%			142%			73%			100%		

Table 4: Overheating Assessment based on Dry Resultant Temperature using AS1 Linford Results (Kew, Huge South Glazing Area)

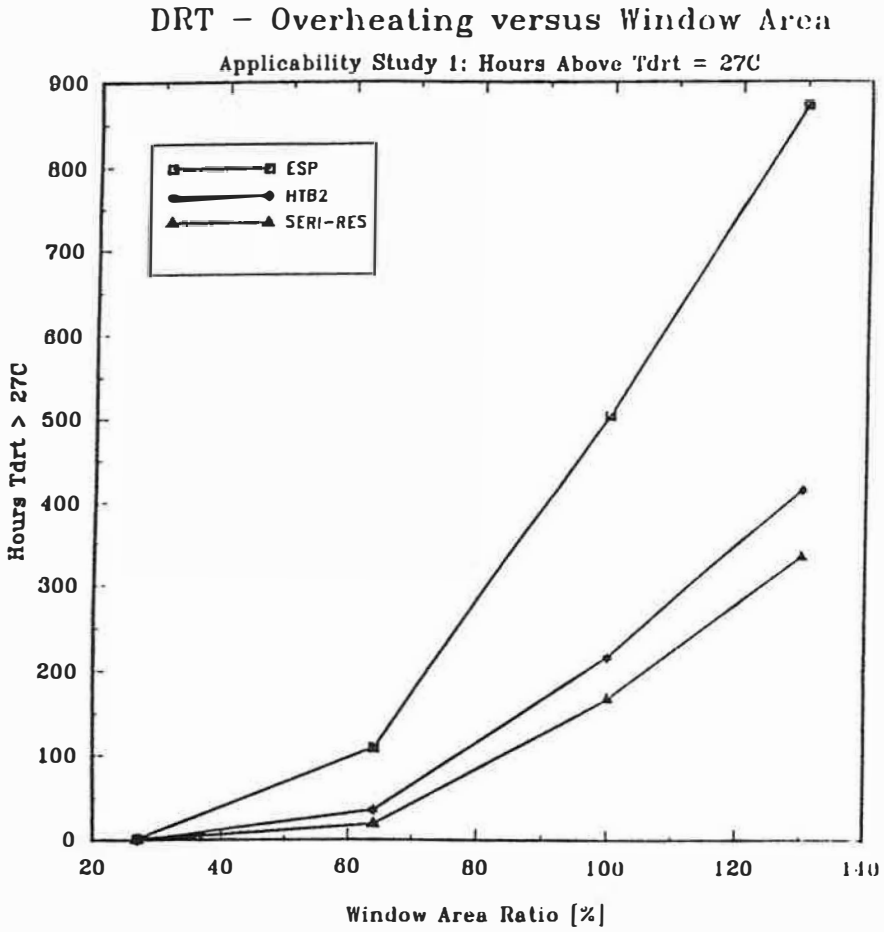

Figure 5: Overheating predictions using Criterion 5 - AS1

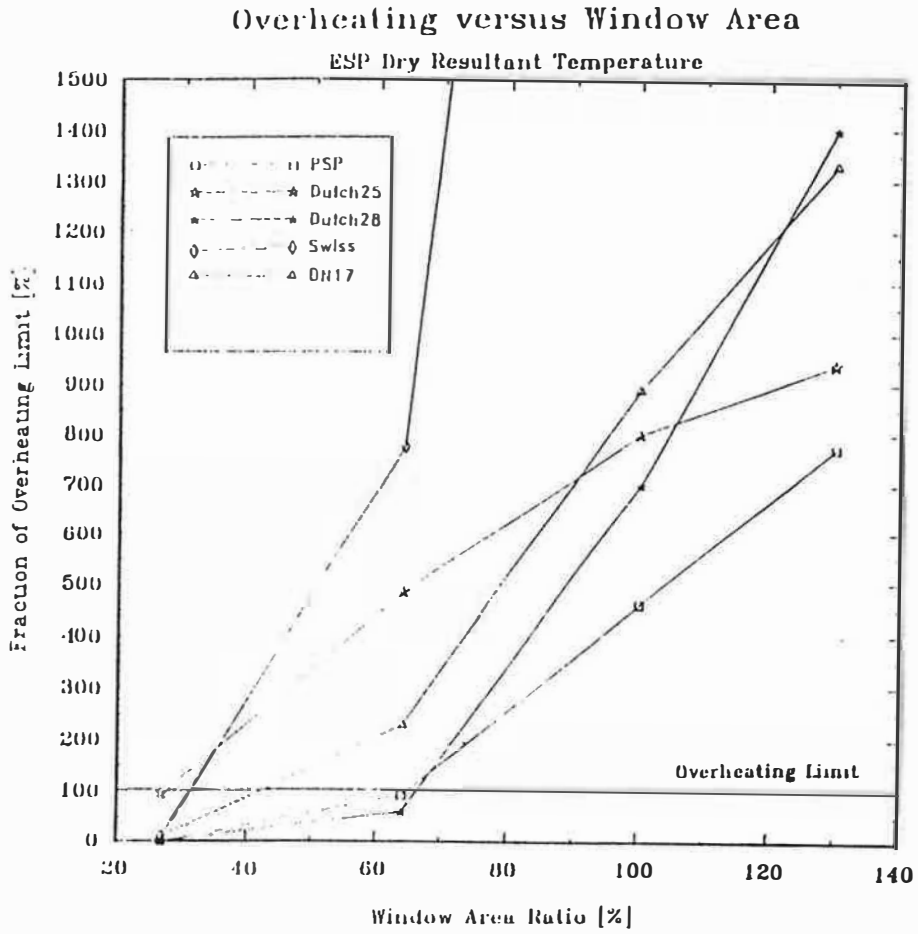

Figure 6: Influence of Criterion on assessment of buildings using ESP

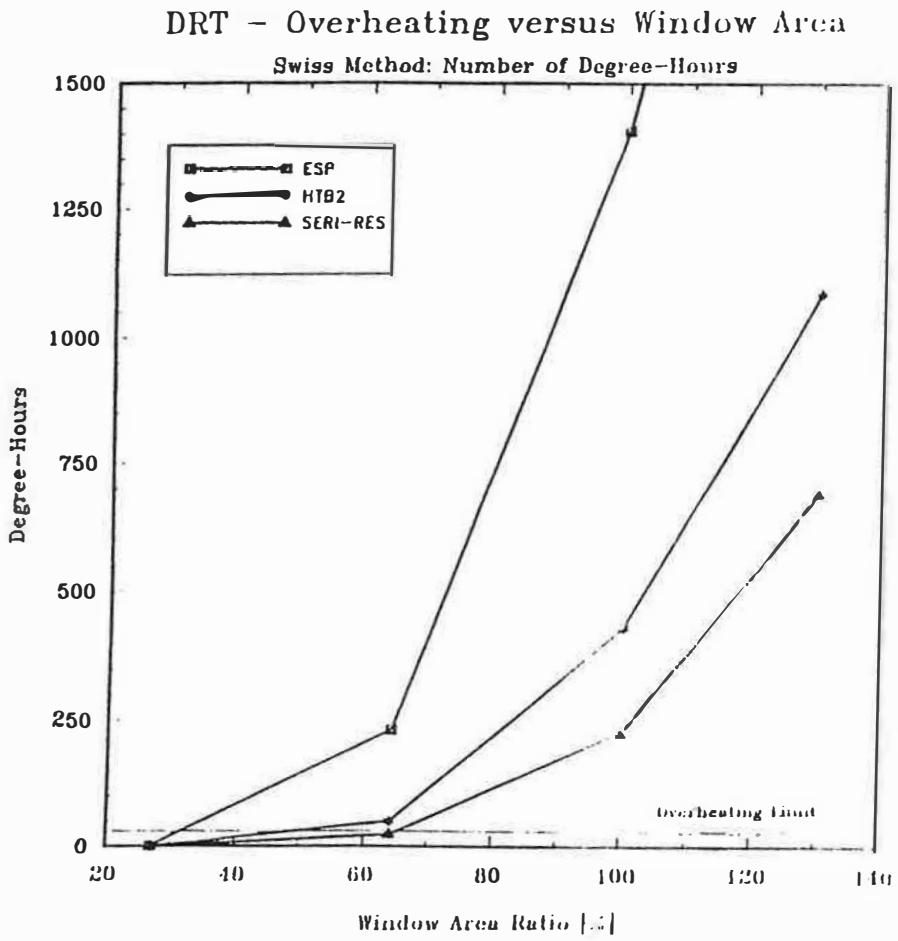

Figure 3: Overheating predictions using Criterion 3 – Swiss

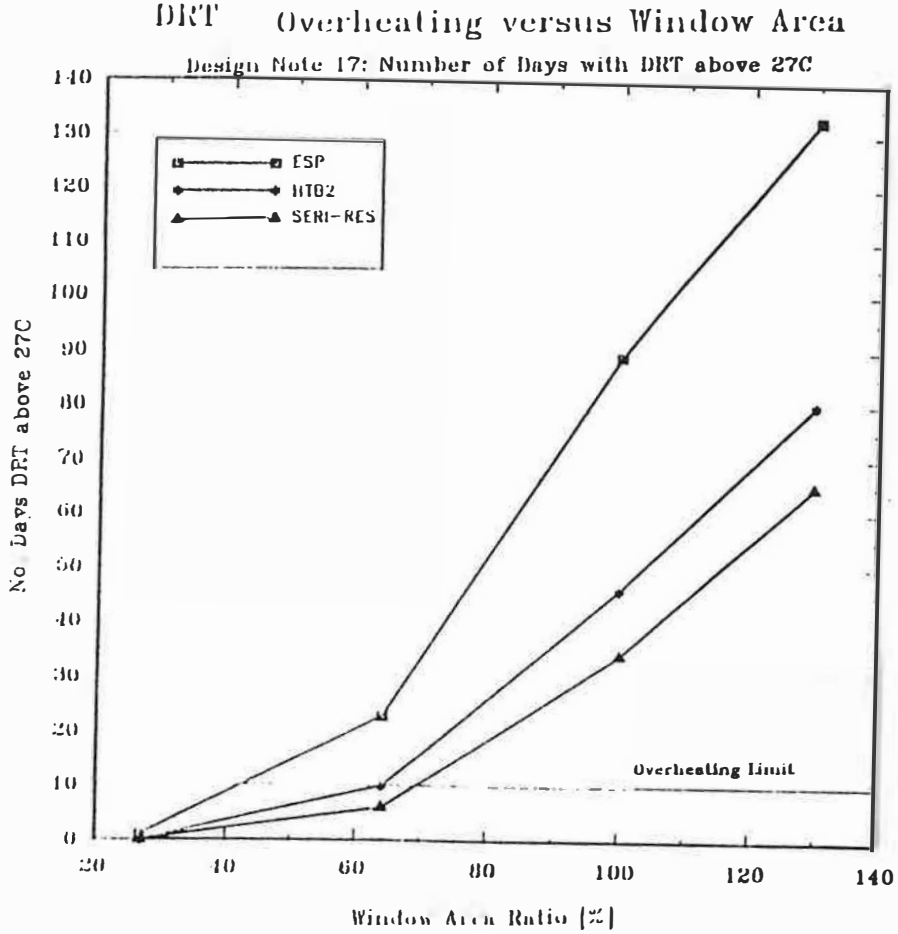

Figure 4: Overheating predictions using Criterion 4 - DN17

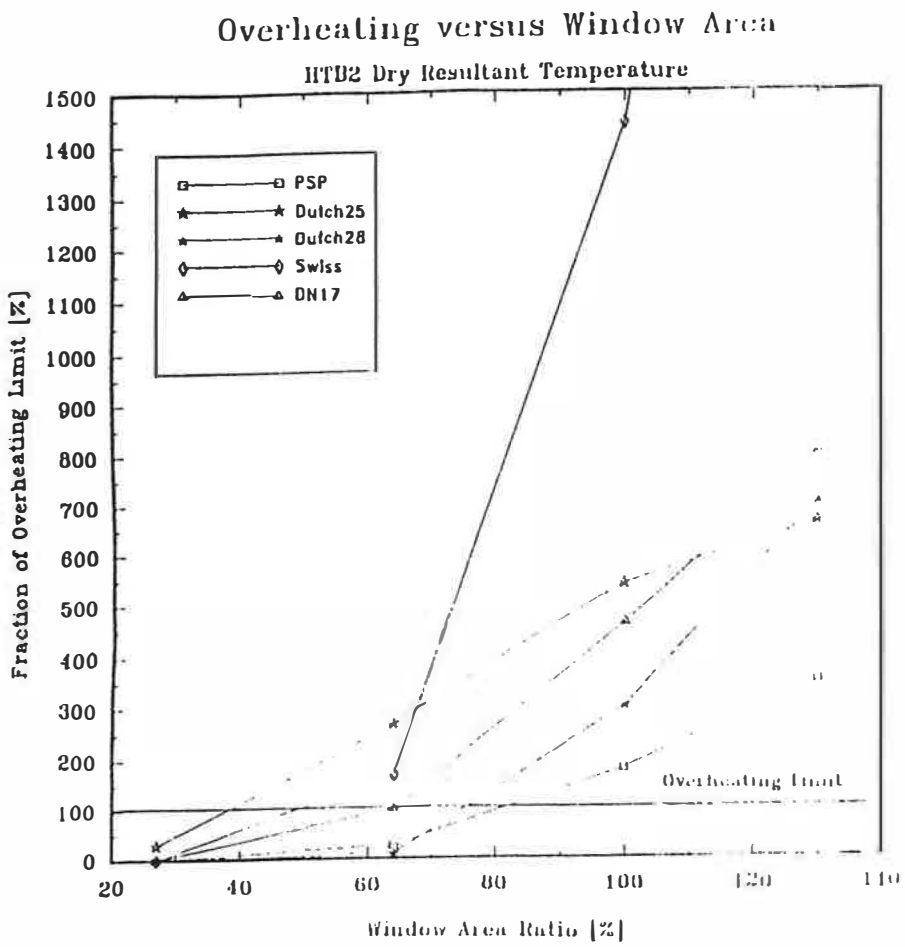

Figure 7: Influence of Criterion on assessment of buildings using HTB2

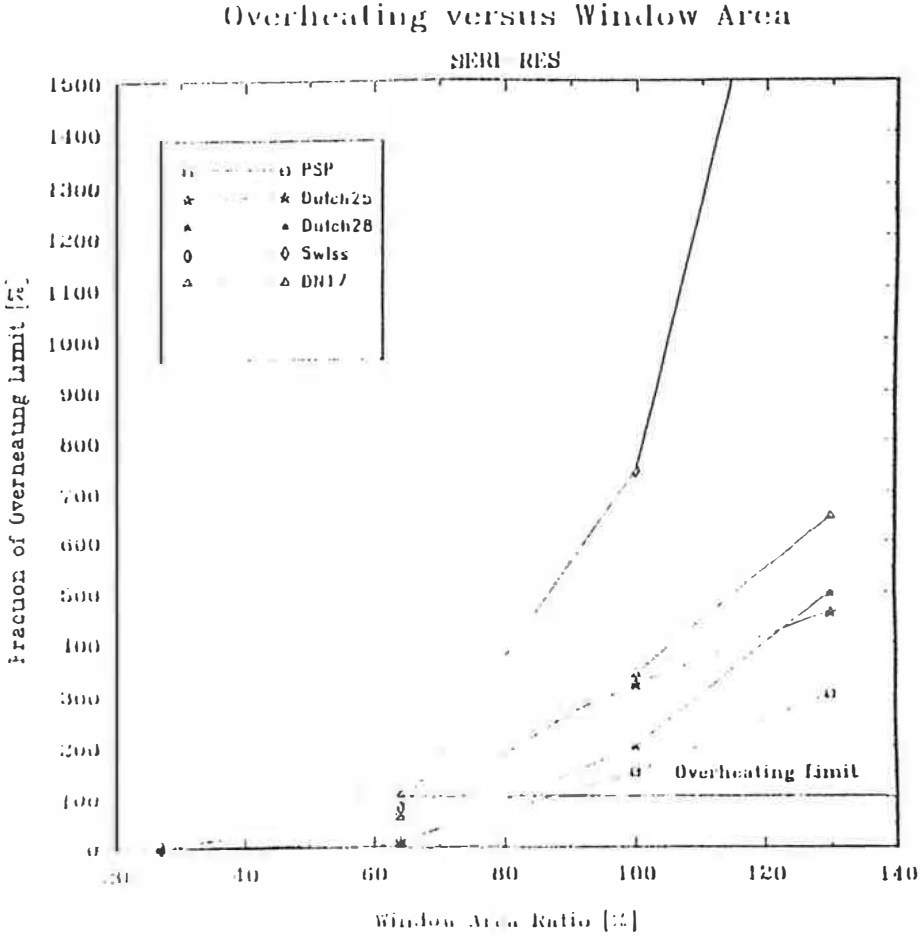

Figure 8: Influence of Criterion on assessment of buildings using SERI-RES

INTERNATIONAL ENERGY AGENCY

CALCULATION OF ENERGY AND ENVIRONMENTAL PERFORMANCE OF BUILDINGS

Subtask B

Appropriate use of Programs

Volume 2

ENERGY CONSERVATION IN BUILDINGS AND COMMUNITY SYSTEMS PROGRAM