#2987

#2987

WEATHER DATA SEMINAR

WHAT'S THE WEATHER LIKE IN THE GUIDE????

M J Holmes
Technical Director, Arups Research and Development, 13 Fitzroy Street, London, W1P 6BQ

The successful design of a building includes the provision of satisfactory environmental conditions at a reasonable first cost and running cost. To do this it is necessary to determine the optimum size of environmental control plant for the building and demonstrate the efficiency of that plant over a typical period of building use. This means that design and operating conditions must be correctly specified, including both intended usage and the environment into which the building will be placed, that is local climatic conditions. To assist the building services engineer in the latter task the CIBSE publish a guide book, part of which is concerned with weather, related to both design and performance. The scope of the Guide in this respect may not be fully realised by many members so this paper attempts to describe what is available and what can be done with it.

INTRODUCTION

The design of a successful building is the result of good team work between architect, structural and services engineers (and a few others). Each has to specify what is required to ensure that his particular contribution meets the client's and team's requirements. To do this it is necessary to make use of 'design data', one particular item is the specification of the environment in which the building is located. At first sight it might appear that the needs of each discipline are different, this is not entirely true, similar data can often be used for different purposes. For example, wind speeds and direction would be used by the services engineer to predict infiltration rates, the architect might make use of the same information to study the effect of building form on the local micro-climate, and so prevent the induction of high wind speeds at street level due to the interaction between the new building, wind and existing structures. The structural engineer would need the data to ensure that the building did not fall down. Similar solar data might be employed, in the case of the structural engineer to avoid unacceptable differential expansion, the architect might want to study daylighting and shade to meet the services engineer's requirement to prevent overheating.

In some cases identical data will satisfy the needs of all, in others such as structural performance the engineer will require his wind data on quite a different basis to that used for ventilation analysis. The reason for this is obvious, in the case of the former the design objective is to reduce the possibility of a catastrophic failure to a very low probability. Ventilation calculations are more concerned with what might happen under typical operating conditions. This is not to say that the services engineer does not design to a specified failure rate, it would not be cost effective to size plant for all possible weather conditions, the point is that whilst the same data might appear suitable for a number of applications it will not always be so. The latter is true across and inside professions. Design weather data is not suitable for use in predicting energy consumption because by it's nature it is not typical, nor incidently is average data necessarily suitable. Within each section of building engineering there is a need for guidance on the most appropriate weather data for a particular application. The CIBSE GUIDE meets this requirement for the building services engineer.

Those familiar with the Guide will know that the majority of weather data is contained in section A2, there are however relevant data in other sections, notably C1. Section C1 is concerned with the properties of humid air, and whilst not obviously weather data, a good understanding of psychrometics is essential if proper use is to be made of meteorological measurements. Psychrometrics is discussed in another paper(1) at this seminar and therefore no more will be said here.

As well as presenting the data in the Guide the CIBSE includes the data in some other publications, covering both design and energy consumption. These are:

CIBSE Energy Code Part 2.
Design Notes for the Middle East (in process of revision)

In the case of the former the requirement is, at present, limited to average temperatures over the heating season, this will however be expanded to include most weather parameters when part 2c (air conditioned buildings) is published. The Design Note is of great value to anyone designing for that part of the world. Further discussion of these is beyond the scope of this paper, they are mentioned here for completeness. This paper is solely concerned with data contained in Section A2 of the 1987 CIBSE GUIDE, that is related to the design of buildings.

The content of A2 is vast so it is not possible to cover every section in a single paper. In addition some information is related to the prediction of energy usage. The CIBSE Example Weather Year(1, 2) is such a case and can be ignored here because it again is the subject of another paper at this symposium, as are most energy related data. It is also anticipated that most engineers will be fairly familiar with section A2 prior to the 1976 version (when the banded weather data was introduced) this paper is therefore more concerned with changes than a detailed discussion of content. In addition, there appear to be some anomalies in the data, these are highlighted with the hope that future editions will put everything right.

The paper follows the general layout of the Guide and after general discussion of the meaning of design data presents cold weather followed by hot weather data. It is by no means a full description rather a commentary, a more detailed description is given by Petherbridge and Oughton(3).

1. THE CONCEPT OF DESIGN DATA

Successful design is the result of careful appreciation of what is required and selection of the best way to ensure that the product meets this specification. In the present context this means that conditions within a building will be acceptable to the 'majority' of the occupants. The emphasis on the majority is very important because it has to be recognised that no design can be 100% successful, people differ and it is probable that only 80% of a large population will vote a particular condition to be comfortable(4), whatever the condition. This fact should not cause fits of depression amongst the perfectionists but an appreciation of realism in that there would be complaints even if the plant had infinite capacity. The provision of infinite capacity would of course be a disaster in terms of both capital and running costs so it is necessary to select some condition that, whilst not too extreme, will ensure that environmental conditions within the building are acceptable to most occupants for most the time. The best way to do this is to first determine what internal conditions will meet the demands of thermal comfort and then size the plant to provide these - accepting that occasionally there will be failures due to an unusual external environment. Thermal comfort is not the subject of this paper, those who wish for a discussion of this topic are referred to Fanger(4) and Section A1 of the CIBSE Guide. The only concern here is whether the choice of external design condition can be influenced by the requirements for thermal comfort. This is most unlikely because once plant has been selected to meet an extreme, then provided sensible components have been selected and the controls function, all other conditions (less extreme) will be satisfied. Is therefore, the selection of appropriate external design conditions limited to simple statistical analysis of weather, or can the building have an influence on what is required? To answer this it is convenient to look at heating and cooling design separately.

1.1 Design Weather for Heating

Conventially heating is divided into continuously and intermittently heated buildings, so the first question must be; is different data required to size the plant for the two modes of operation?

It is not too much of a simplification to say that a building can be represented by a linear electrical analog comprising resistors and capacitors. Such a system can be characterized by a steady-state response and a dynamic one that is directly proportional to the steady-state response. The response of a simple circuit to a step function demonstrates this:

$$V = V_o\left\{1 - \exp\,(- t/RC)\right\} \qquad (1)$$

Any output (V) can be obtained at a specified time (t) by varying the input V_o. This means that if V_o is equal to the required steady- state value ($t = \infty$), provided the value of RC is known, a simple oversize factor can be used to ensure the steady-state (design value) of V is reached at a specified future (pre-heat) time.

It is therefore, reasonable to assume that the same design weather data can be used for both continuous and intermittently operated plant. In the latter case it will be necessary to have some knowledge of the dynamic characteristic of the building so that an appropriate oversize factor can be selected. This aspect of design is covered in Sections A5 and A9 of the Guide.

The steady-state loss of heat from a building can be calculated from an equation of the form:

$$Q = \sum AU\ (t_{ei} - t_{eo}) + C_v\ (t_{ai} - t_{ao}) - Q_g \qquad (2)$$

where

Q	is steady state heat loss	(W)
$\sum UA$	is the product of conductance x area for all external surfaces	(W/K)
C_v	is the ventilation conductance	(W/K)
Q_g	represents internal and external gains	(W)
t_{ei}	is the internal environmental temperature	(°C)
t_{eo}	is the external environmental temperature	(°C)
t_{ai}	is the internal air temperature	(°C)
t_{ao}	is the external air temperature	(°C)

Three weather parameters are included in Equation 2, t_{eo}, t_{ao}, and part of Q_g. The difference between t_{eo} and t_{ao} is that the former is a sol-air temperature and therefore for horizontal surfaces at night could be about 4K lower than the air temperature. During the day t_{eo} will rise above the air temperature because of solar gains. It may therefore be necessary to use different design temperature for different surfaces. The daily average value of t_{eo} is probably not too different from t_{ao} and because of the complexities involved to do otherwise, it is usual to assume the two temperatures are identical. (The selection of a design dry bulb would not be influenced by a distinction between the two because the clear night sky is at a constant temperature, so the effective temperature reduction due to long wave loss will be constant).

This effective lower outside temperature may be significant in the selection of overall plant size for low rise buildings and for the system in the top floor of any building. It might, therefore be possible for building form to influence the selection of design data. Increase in insulation levels over the years make this unlikely now, but perhaps this possibility should be borne in mind when looking at old or unusual buildings (atria for example).

Conventionally, heat gains (Q_g) are ignored in the design of a heating system because:

With intermittent heating they will not usually be present during the pre-heat period.

With continuous heating again there will be times when the plant will be run with no assistance from gains.

In both cases the building must be at a suitable temperature for occupancy. The selection of design data for heating might therefore be done by examining temperature distributions such as that in Figure 1 (which is for the CIBSE Example Year for Kew), deciding upon a failure rate (say 2½% of the heating season 5000 hours), the temperature that is exceeded for more than 125 hours is then the design dry bulb temperature. This simplistic approach ignores the hidden weather parameter in Equation 2, wind speed. Both U and C_v are a function of wind speed. It could therefore, be seen as necessary to consider correlations between dry bulb and wind speed in the selection of the most appropriate weather data for the site. The heat loss equation might thus be written:

$$Q = \frac{A}{B + CV_w} (t_{ei} - t_{eo}) + C_{vo} (1 + DV_w^{\,n}) (t_{ai} - t_{ao}) \qquad (3)$$

where

V_w is the wind speed (m/s)

C_{vo} a reference ventilation rate. (hr^{-1})

n, is an exponent (arbitrary here) to correct and C_{vo} (a basic ventilation rate) for wind speed

A, B, C, D are constants

The most appropriate correlation might then be the frequency of occurrence of dry bulb multiplied by wind speed (raised to some power). This means building form and detailed site layout becoming involved in the selection of design data. The complexities are obvious, and probably unnecessary. Ventilation will be provided by either mechanical means or passively through windows (which are unlikely to be open more than necessary on a design day). In both cases the design ventilation rate can be taken as independent of the weather. Infiltration is another matter, however if it was to exceed the usual ventilation allowance there should be serious questions as to the quality of construction. The effect of wind speed on 'U' value can be accounted for by considering general site exposure - in any case with the exception of glazing the effect will be small. This might mean that greater care should be taken with in the selection of design conditions for highly glazed buildings such as atria and greenhouses.

To select suitable design conditions, coincident wind speed and temperature data are necessary, such information is available from the Meteorological Office. Unfortunately to obtain statistically significant results it is necessary to analyse about 20 years data. Suitable data are not contained within Section A2.

The following example shows what might be done for a flat single-glazed roof using the CIBSE Example Weather Year as the data source (Note this is an example and should not be used for actual design purposes).

The rate of loss of heat through a flat single glazed roof can be written as:

$$Q_r = \frac{(t_i - t_o)}{(R_{si} + R_{so})} \qquad (2)$$

where for design purposes:

R_{si} the internal resistance is 0.1 (m²K/W)

R_{so} the external resistance is $1/(Eh_r + h_c)$ (m²K/W)

Section A3 of the 1970 CIBSE Guide gives the value of the convection coefficient he as:

$$h_c = 5.8 + 4.1\, V_w \quad (\mathrm{W/m^2K}) \qquad (5)$$

where V_w is the wind speed (m/s)

The emissivity factor E can be taken as 0.9 and the radiant coefficient h_r:

$$h_r = -4\,\sigma\,(t_g + 273)^3 \quad \mathrm{W/m^2K} \qquad (6)$$

where t_g is the surface temperature of the glass

$$\text{and } t_g = t_i - R_{si}\, Q_r \quad (^\circ\mathrm{C}) \qquad (7)$$

So the roof heat loss becomes:

$$Qr = \frac{(0.9h_r + h_c)(t_i - t_o)}{(0.09h_r + 0.1h_c + 1)} \quad (\mathrm{W/m^2}) \qquad (8)$$

Equation 8 can be solved iterativily with (7) and (6) to give the design heat loss for various wind speeds and temperatures. This has been done using the wind analysis presented by liddament(5) Figure 2 gives the percentage of the heating season (210 days) for which specified values of heat loss are not 'exceeded'.

A design temperature cannot be derived directly from Figure 2, it is necessary to first set the failure rate and, then using a standard wind speed (3 m/s) calculate the temperature that corresponds to the heat loss at the failure rate.

Taking a failure rate of 2½% the heat loss is 139 W/m², which corresponds to an external temperature of zero when the wind speed is 3 m/s. This can be compared with the corresponding figure selected from dry bulb alone in Figure 1 of -0.8°C. In some cases it may therefore be necessary to analyse the performance of a building of a range of conditions if a realistic design temperature is to be obtained.

1.2 Design Weather for Cooling

The concept of correlations introduced in Section 1.1 is far more important when cooling is the objective. In the case of heating it was stated that after calculation of the steady state load, factors can be used to determine the requisite plant size to ensure that the building is heated to comfort levels by the start of occupancy. This results in the possibility to trade off plant capacity against pre-heat times. With cooling, maximum loads occur during occupancy, and unless special means are taken in the design of the building and system it is unlikely that pre-cooling will have very much effect on plant capacity. The result of lowering the air temperature prior to an expected peak load might not be appreciated by many occupants.

The load on an air conditioning plant comprises a room and outside air component. The former depending on solar radiation and air temperature (dry bulb), together with the sensible and latent internal gains. If wind speed can be ignored it would then appear necessary to examine correlations between solar radiation, dry bulb and wet bulb. For mechanically and naturally ventilated buildings where prediction of peak temperatures instead of peak loads is the objective, correlations between solar radiation and dry bulb are necessary. How might design values be selected?

In the case of air conditioning plant it is usual to treat the room and outside air loads separately. Thus the selection of a design outside air load might make use of a failure rate based on enthalpy or dry bulb. One way to do this is is to divide the psychrometric chart into regions on the basis of the fraction of the summer months conditions which lie within set limits (this method is taken further in another paper to be presented at this seminar (6)). The selection of suitable design conditions for the calculation of room loads or peak temperatures can be more complicated.

The room cooling load will (unless there are high internal gains) usually be closely related to the level of solar radiation. A simple method to select suitable design data might therefore be based on the frequency of occurrence of high solar radiation.

At first sight this is all that is necessary, because unless the infiltration rate is very high the effect of the outside air dry bulb will often be of second order: but should the selections be based on direct or diffuse radiation?

The obvious answer is that if the building has shading then direct solar radiation will be great importance. The converse applies to well shaded buildings, but what about buildings that fall between these extremes? The best way to approach this difficulty is to carry out design calculations for a number of different climatic conditions - which is trivial if a computer is employed. The likely results of such an analysis are that high solar radiation will be important where the building is air conditioned, using conventional plant, with high dry bulb an important consideration for non-air conditioned buildings. High internal gains will, of course, mask the significance of the design weather data in the calculation of peak cooling loads but the correct selection of design conditions for the plant will become more important.

The only way to understand the effect of interactions is by examples - unfortunately examples are specific and cannot be extrapolated - however one is given here to bring a little realism to the discussion.

The example is a simple office module 5m x 4m x 5m high, with a single external 5m long wall, facing South. This wall U-value is 0.6 W/m²K and has a single double glazed window occupying 40% of the area. Using the banded weather data in Tables A2.7 and A2.8 air conditioning loads (dry bulb set point 23°C) are given in Figure 3a for a range of internal gains in excess of these created by 3 occupants. Corresponding calculations are given in Figure 3b for a mechanically ventilated office (6 air-changes from 0900 to 1800 hours, and a 1/4 of an air-change at night) with and without external shade (0.4m over hang). The content of Tables A2.7 and A2.8 is discussed in Section 2.2. The design weather data used here were for July and based on the assumption that values would not be exceeded for more than 2½% of that month.

The simple conclusions are that the peak room air-conditioning load is not very sensitive to the basis of the selection, whereas the peak summertime temperature is. In addition, as might be expected the well shaded example shows greater sensitivity to the basis of the data (banded on solar radiation or dry bulb) used in the calculation.

Whilst it cannot be disputed that the differences shown here are small, this may not always be so. It is therefore necessary to approach the selection of design solar data carefully. In addition it should be remembered that design often involves proving that specified conditions will not be exceeded, in this case small differences can be important.

2. DESIGN WEATHER DATA IN A2

In the present case this is taken to mean heating and cooling data suitable for use with standard CIBSE calculation techniques. Wind, precipitation, daylight availability and atmospheric pollution data are therefore excluded. However, it would be unfair to the A2 Task Group to avoid all mention of these topics. The best way to show the scope of A2 is to look at the index which is repeated here as Table 1 only the underlined headings are considered in this paper. Much of the remaining content will be addressed by other papers presented at the symposium. (See Table 1)

One important section that will not be discussed in detail here - mainly because it is self-explanatory - is World Weather Data. This comprises a set of Tables (A2.22) giving summer and winter design temperatures, precipitation and annual hours of sunshine for most of the world. The data are based on information available from the Meteorological Office and the

ASHRAE Guide. It is important to note that there are some changes from previously published values, probably due to the selection method which is discussed in Section 2.2.4 of this paper.

2.1 Cold Weather Data

"An analysis of cold weather data is required to establish the external design temperatures to be used in sizing a heating plant and it's associated distribution system". (A2.4). The previous section has indicated the need for a statistical approach to the selection of suitable design temperatures, and this is what is done in this section of the Guide. The design risk assessment is not solely based on the weather but includes the thermal inertia of the building. The reason for this is that a building with low thermal inertia will follow weather patterns more closely than a very heavy building. The low mass building is assumed to respond to single day average temperatures whilst one of high mass will follow temperatures averaged over pairs of days. Examples of high and low mass buildings are given multi-storey and single storey respectively, but a reference to Section A5 would not go amiss. So a design temperature for a low mass building will be such that "on average only one day in each heating season has a lower mean temperature", for high mass replace 'one day' with 'two day spell'. To make such an assessment a statistical analysis of weather data is required, suitable information is included in A2.

TABLE 1 Content List for A2

A further complication is now introduced (in A2), the system overload capacity. It is assumed that in the UK unless the building is occupied continuously the plant should not be run continuously. This means some excess capacity to enable pre-heating to be done in a reasonable time. Section A2 states "The temperature given in the table (design values) normally can be safely used with system having 20% overload". Whether this implies some guarantee of performance under intermittent operation is questionable, what may be of concern is the suggestion that the design temperature should be adjusted to meet the needs of different overload capacities. This is putting the cart before the horse. What should be done is to use the design data to select the plant for zero or small overload and then determine the appropriate overload capacity for the intended method of plant operation. This can be done using theories described in Section A5. The building is a climate modifier and therefore it is reasonable to take its' effect into consideration when sizing the plant. The plant responds to control functions and cannot moderate the weather, the way it is used should therefore not be included in the selection of design data. The Guide has however taken the opposite view, giving advice on the most appropriate design temperature for systems with and without overload capacity. The basic advice is to reduce the design temperature by 2½°C - equivalent to an approximate overload of 10% which may be seen as rather strange.

2.2 Warm Weather Design Data

This part of the Guide appears to have suffered most revisions. The intention of the revisions appears to be to bring the design condition data closer to reality, in particular to recognise that solar radiation levels and dry bulb temperature are somewhat correlated. This is not to say that previous Guides ignored this, Table A 8.3 in the 1971 Guide gives temperatures for days with high solar radiation, but now also included is the fact that the split between diffuse and direct radiation varies with dry bulb.

So what is contained and how is it used?

Table 1 shows the range of content, it can be seen that considerable emphasis is placed on the calculation of the Sun's position relative to the Earth (A.53 to A.57). Once again this is not weather data but information that is necessary to make use of the data in the same way as the psychrometric information contained in Guide Book C. Further the Section only goes half way in being useful, in that the way to calculate the solar position is missing, although only tables (A2.23) of solar altitude and azimuth are contained - not so useful in the world of the micro-computer. Additionally, mention is made of how to calculate the angle of incidence between a building surface and the sun for very simple situations again a case for further development in a separate Guide Section. The remainder of the Section concentrates on modelling solar radiation.

2.2.1 The A.2 Solar Radiation Model The most important thing to remember here is that the objective is design and not the simulation of building performance under typical operating conditions - although some of the data might be just about suitable for that purpose. The first thing thing a reader will be aware of is the introduction of cloudy day diffuse radiation. This is because two models of solar radiation are now offered:

A clear sky model - as previous Guides.

A cloudy sky model which will be new to many.

The former is stated to only give good agreement with measured data when there is no significant cloud, the second model is more generally applicable. In both cases two sky clarity factors are necessary:

k_D applicable to direct radiation

k_d applicable to diffuse radiation

In the case of the clear sky model k_d is unity. The two factors are defined as:

For clear skies

$$k_D = \frac{\text{(Measured total radiation - Basic diffuse (clear sky) radiation)}}{\text{Basic direct radiation}}$$

For cloudy skies replace (clear sky) with (cloudy sky) and again k_d is unity.

Real skies are said to fall between the two so in this case:

$$k_D = \frac{\text{measured direct radiation}}{\text{basic direct radiation}}$$

$$k_d = \frac{\text{measured sky diffuse radiation}}{\text{basic cloudy sky diffuse radiation}}$$

In both cases the measurements are 24 hour averages and exclude any ground reflected components.

The basic value taken for direct radiation is as in previous Guides (3) from Moon with the clear sky radiation as given by Loudon(3). The 'new' cloudy sky diffuse is also based on work by Loudon (apparently not yet published) which gives an enhanced level of diffuse radiation on cloudy days. The two values of sky diffuse radiation are compared in Figure 4 There is clearly need for guidance as to which to use and when.

The 'new' A2 has adopted the clear and cloudy sky model as the basis for the selection of design solar irradiance. The successful use of this model requires long term measurements of radiation for the site. Suitable data exist for only a few UK sites and it would appear that only South-East England is considered in detail in the Guide. The design irradiances are calculated for this region on the basis that they are likely to be exceeded on no more than 2½% of occasions. The full data are not reproduced here, only the values of k_D and k_d are given (see Table 2)

Table 2 Solar correction factors for design weather in South-East England. (Guide Table A2.27)

Month	Direct factor k_D	Diffuse factor k_d
June	0.82	0.66
July/May	0.72	0.89
Aug/April	0.73	0.93
Sept/March	0.88	0.97
Oct/Feb	0.83	1.18
Nov/Jan	0.88	1.29
December	0.97	1.18

The factors given in Table 2 would appear to be obtained from the banded weather data for Kew given in Tables A2.7 and A2.8, and averaged where pairs of months are considered. The precise way in which the values were obtained is not at all clear from the Guide or reference 3.

2.2.1.1 Banded Weather Data An example of these data is given in Table 3, for the month of July (taken from Table A2.7 and A28) (The same values as used in the example given in Section 1.2). So how were the numbers obtained and what do they mean, and more important, what can be done with them? (See Table 3)

Basically using a sample 10 years long, each month was divided into pairs of consecutive days. Mean values of all the parameters given in the heading of Table 3 were calculated. These values were then put into 'bins' selected either on the basis of daily mean solar irradiance or daily mean dry bulb. Ten bins were used for each. In the example given, the bin widths, and range are:

Solar radiation bins: maximum mean level : 27.06 MJ/m²
minimum mean level : 3.96 MJ/m²
bin width : 2.31 MJ/m²

Dry bulb bins: maximum mean level : 23.4°C
minimum mean level : 12.1°C
bin width : 1.13°C

These bins are given as the second column in the tables, the third gives the proportion of the month for which the range of values within the bin can be expected to be found. The following columns are fairly self- explanatory but it should be noted that:

(a) Long wave radiation loss is given for vertical surfaces
(b) A new model of the variation in dry bulb through the day is used.

Both are discussed later in this paper.

Table 3 Banded Weather Data for July (Upper Based on Solar Radiation)

Month	Band Limits /(MJ/m²)	Proportion of month	Daily Irradiation /(MJ/m²)		Solar factors		Sunshine duration /(h)	Daily Mean long-wave loss /(W/m²)		Dry-bulb/°C			Wet-bult/°C			Daily mean wind speed /(m/s)
			Gobal	Diffuse	K_D	K_d		roof	wall	t_1	t_2	t_3	t_1	t_2	t_3	
JUL	27.06-24.75	0.036	25.60	7.05	0.76	0.72	13.4	80	18	25.8	13.8	20.1	17.4	12.5	15.4	2.6
	24.75-22.44	0.055	23.45	8.56	0.61	0.87	11.9	73	17	22.7	12.2	17.8	15.6	11.1	13.6	2.9
	22.44-20.13	0.087	20.98	9.54	0.47	0.97	10.1	64	15	23.5	14.3	19.1	17.1	13.0	15.3	3.1
	20.13-17.82	0.116	18.89	9.91	0.37	1.01	8.3	55	13	21.3	13.6	17.6	15.5	12.2	14.0	3.4
θ_{max} = 15 GMT	17.82-15.51	0.200	16.56	10.22	0.26	1.04	6.3	45	11	20.0	13.4	16.8	14.9	12.0	13.6	3.3
	15.51-13.20	0.203	14.45	10.18	0.18	1.04	4.5	36	9	19.2	13.4	16.4	14.7	12.1	13.6	3.6
	13.20-10.89	0.171	12.11	9.24	0.12	0.94	3.1	29	7	18.4	13.7	16.1	14.6	12.5	13.6	3.8
θ_{min} = 04 GMT	10.89- 8.58	0.090	9.85	8.23	0.07	0.84	1.8	23	6	18.0	13.4	15.7	14.7	12.3	13.6	3.7
	8.58- 6.27	0.032	7.82	6.88	0.04	0.70	1.2	20	5	17.3	13.8	15.4	14.5	12.8	13.5	3.3
	6.27- 3.96	0.010	4.69	4.37	0.01	0.45	0.1	14	4	17.4	14.8	16.0	15.8	13.8	14.8	4.9
	Average	1.000	15.67	9.37	0.26	0.96	5.8	43	10	20.0	13.5	16.9	15.1	12.3	13.8	3.4

Possible = 16.0

Month	Band Limits /°C	Proportion of month	Daily Irradiation /(MJ/m²)		Solar factors		Sunshine duration /(h)	Daily Mean long-wave loss /(W/m²)		Dry-bulb/°C			Wet-bult/°C			Daily mean wind speed /(m/s)
			Gobal	Diffuse	K_D	K_d		roof	wall	t_1	t_2	t_3	t_1	t_2	t_3	
JUL	23.4-22.3	0.016	24.53	7.53	0.70	0.77	12.8	77	18	29.0	16.2	22.7	19.8	14.8	17.9	2.7
	22.3-21.1	0.023	22.06	7.73	0.59	0.79	10.9	68	16	26.4	15.9	21.5	18.8	14.3	16.9	3.0
	21.1-20.0	0.048	19.03	9.50	0.39	0.97	8.9	58	13	25.0	15.9	20.5	18.7	14.7	16.9	3.0
	20.0-18.9	0.084	19.27	9.15	0.42	0.93	9.0	58	14	23.7	15.1	19.4	17.2	13.6	15.5	3.1
θ_{max} = 15 GMT	18.9-17.8	0.129	16.50	9.68	0.28	0.99	6.2	45	11	21.8	14.7	18.2	16.5	13.4	15.0	3.4
	17.8-16.6	0.197	15.48	9.66	0.24	0.98	5.5	41	10	20.3	13.8	17.1	15.5	12.5	14.2	3.5
	16.6-15.5	0.267	14.92	9.63	0.22	0.98	5.2	40	10	18.8	13.0	15.9	14.1	11.7	13.0	3.6
θ_{min} = 04 GMT	15.5-14.4	0.184	13.32	9.13	0.17	0.93	4.1	34	8	17.5	12.2	15.0	13.6	11.1	12.5	3.3
	14.4-13.2	0.042	13.00	9.11	0.16	0.93	4.0	34	8	15.9	11.4	13.9	12.1	10.0	11.2	4.0
	13.2-12.1	0.010	13.20	9.42	0.16	0.96	3.0	29	7	15.1	9.5	12.6	10.8	8.2	9.6	2.9
	Average	1.000	15.67	9.37	0.26	0.96	5.8	43	10	20.0	13.5	16.9	15.1	12.3	13.8	3.4

Possible = 16.0

t_1 = Max

t_2 = Min

t_3 = Mean

Values of K_D and K_d appropriate to the 2½% criterion used in the example (1.2) and the design irradiance and all other relevent parameters are found by interpolation with in Tables 3.

Thus the banded weather data is useful in selecting design data for a specific failure rate. It is a great pity that only Kew data are given in the Guide. One reason for this may be the costs involved in obtaining data and the subsequent analysis.

A further use of these data is in modelling the performance of a building over a range of average conditions. Summertime temperatures (for example) can be calculated for each of the bins used to band the data and performance spectrum obtained. This might take the form of a plot of how many hours specified peak temperatures are exceeded.

2.2.1.2 Long Wave Radiation Loss Just as radiation interchanges occur between the internal surfaces of a room so do the external surfaces radiate to their surroundings. To avoid complexities in calculating this loss it has been assumed that the radiation between the surface and a black body at air temperature is a good model. Previous versions of the Guide have made a further approximation in assuming that the loss only occurs on roofs, that from the walls being compensated by a gain from the surroundings. The new A2 makes use of research by Cole (6) and gives the following models of long wave radiation loss:

Loss on the horizontal = 93 - 79C (W/m²)

Loss on the vertical = 21 - 17C (W/m²)

where C is the cloud cover factor in tenths.

This, obviously more realistic model, along with the revised short wave model means that there are significant changes to the previously published sol-air temperatures in the Guide (Tables A2.33). This is further discussed in Section 2.2.3.

2.2.2 The Dry Bulb Model Examination of the sample banded weather data in Table 3, shows four parameters that can be used in the prediction of hourly dry bulbs:

Time of occurence and level of maximum temperature

Time of occurence and level of minimum temperature.

For the July data given in Table 3, the times are (GMT)

Maximum 1500 hours

Minimum 0400 hours

so a simple sine wave can no longer be used. The model presented in the Guide uses two sine wave curve fits. One with a period equal to twice the time between maximum and minimum temperature (26 hours in the present example) and a second between minimum and maximum (22 hours). The maximum and minimum values of temperature used for the fit are of course those displayed in Tables A2.7 and A2.8.

2.2.3 Sol Air Temperature Tables It is not necessary to go into too much detail here, but to note that whilst the concept of sol-air temperature has not been changed, the values used in the calculation have. These changes have already been discussed (long wave loss 2.2.1.2, the dry bulb curve fit 2.2.2 and for South-East England at least, the radiation data). The sol-air temperatures for South-East England are given in Tables A2.33 for 2½% days of highest radiation. The values in these tables are calculated from the equation:

$$t_{eo} = (aI_{THd} - EI_{l})\,R_{so} + t_{ao} \qquad (^\circ C)$$

where t_{eo} = sol-air temperature (°C)

t_{ao} = dry bulb (°C)

a = solar absorptance

E = long wave emissivity factor

I_{THd} = Total radiation incident on surface (W/m²)

I_{l} = Long wave loss (W/m²)

R_{so} = Surface resistance (m²K/W)

Assuming that the values given in Tables A2.33 are based on information contained in the current A2 the sol-air temperature will be calculated for a vertical, south facing surface at 1500 hrs in July.

The non weather data related parameters of emissivity and absorptance are stated to be 0.9 for dark surfaces, whilst no value of R_{so} is stated, 0.07 m²K/W would, from an example, appear to be implied.

The solar radiation data are said to be taken from Table A2.27 with the corresponding dry bulbs in Table A2.28. Since these are based on the Kew measurements it should at first sight be possible to derive then from the banded weather data. Examination of Table 3 would suggest for a 2½% limit:

$K_D > 0.76$

$K_d < 0.72$

max dry bulb > 25.8

min dry bulb > 13.8

whereas A2.27 gives K_D as 0.72 and K_d as 0.89, with maximum and minimum dry bulbs (A2.26) of 24.6°C and 12.9°C respectively. There would appear to be an inconsistency here.

If we proceed on the assumption that the banded weather data cannot be used for this purpose then, the dry bulb at 1500 hrs in July would be 24.4°C (A2.28) with the corresponding total radiation on a south facing surface 340 W/m² (A2.27). The sol-air temperature is therefore (assuming a non-substantiated long wave loss of 18 W/m² (A.2.33))

$$t_{eo} = (0.9 \times 340 - 0.9 \times 18) \times 0.07 + 24.4°C = 44.7°C$$

This has to be compared with the Guide value of 40.5°C.

To obtain a value of 40.5 it is necessary to use a surface heat transfer coefficient of 18 W/m²K, or R_{so} = 0.055 m²K/W, which is not obvious from A2.

2.2.4 Design Temperatures Previous sections have been concerned with the selection of coincident design solar radiation and temperatures for the calculation of the heat load on a room. As previously discussed the design of air conditioning systems requires that the maximum outside air load be determined. An approximate method for doing this is given in A2. This was used to obtain the world values given in A2.22.

The design dry bulb	is the highest average monthly maximum dry bulb.
The design wet bulb	corresponds to vapour pressure derived from the average daily maximum dry bulb and average daily minimum relative humidity combined with the design dry bulb temperature.

Conclusions

Section A2 contains most of the information required for design in South-East England, it is unfortunate that similar data are not available for the rest of the U.K. The solar radiation model now proposed is probably an improvement on the previous one, however it is not of great use if suitable data for its implementation are not available. Are we to believe that different models must be used for different location, or perhaps that only S.E. England merits the best model, I hope not.

Cross-referencing between various sections and within sections appears to be poor, in particular the data used for cooling load calculations in A9 is not explained in either Section.

The sources of data used in Tables are not clear in particular the relationship between banded weather data, design irradiances and design temperature. It is not enough to present data and expect an intelligent user to accept it without question, if the basis not clear then there can be little confidence in the information.

The title of this paper begs an answer, I think it is 'Quite Good' and the outlook is excellent, provided a little work is done. The most effective way to get this work done is to pay for it. The CIBSE should therefore look into ways to obtain the necessary finance to re-write some of Section A2. In this the membership could help by giving encouragement and suggestions for sources of funding.

References

1. Irving S.J. The CIBSE Example Weather Year. CIBSE Weather Data Symposium. Balham 9 March 1988.

2. Hitchin, Holmes, Hutt, Irving, Nerrala. The CIBSE Example Weather Year, BSER&T, 4(3), 119-124(1983).

3. Petherbridge P and Oughton D.R. Weather and Solar data. A review of information in the CIBS Guide Section A2 (1982) BSER&T, 4(4), 147-158 (1983).

4. Fanger PO. Thermal Comfort, Danish Technical Press. Copenhagen 1970.

5. Liddament M.W. The applications of CIBSE Example Weather Year Data to Air Infiltration and Ventilation Calculations. CIBSE Weather Data Symposium. Balham 9 March 1988.

6. Legg. R. The Use of reduced weather data for energy calculation. CIBSE Weather Data Symposim. Balham 9 March 1988.

7. Cole R.J. The Longwave radiation incident upon the external surfaces of buildings. Build Serv. Eng. (CIBS), 44, 195-206, (1976).

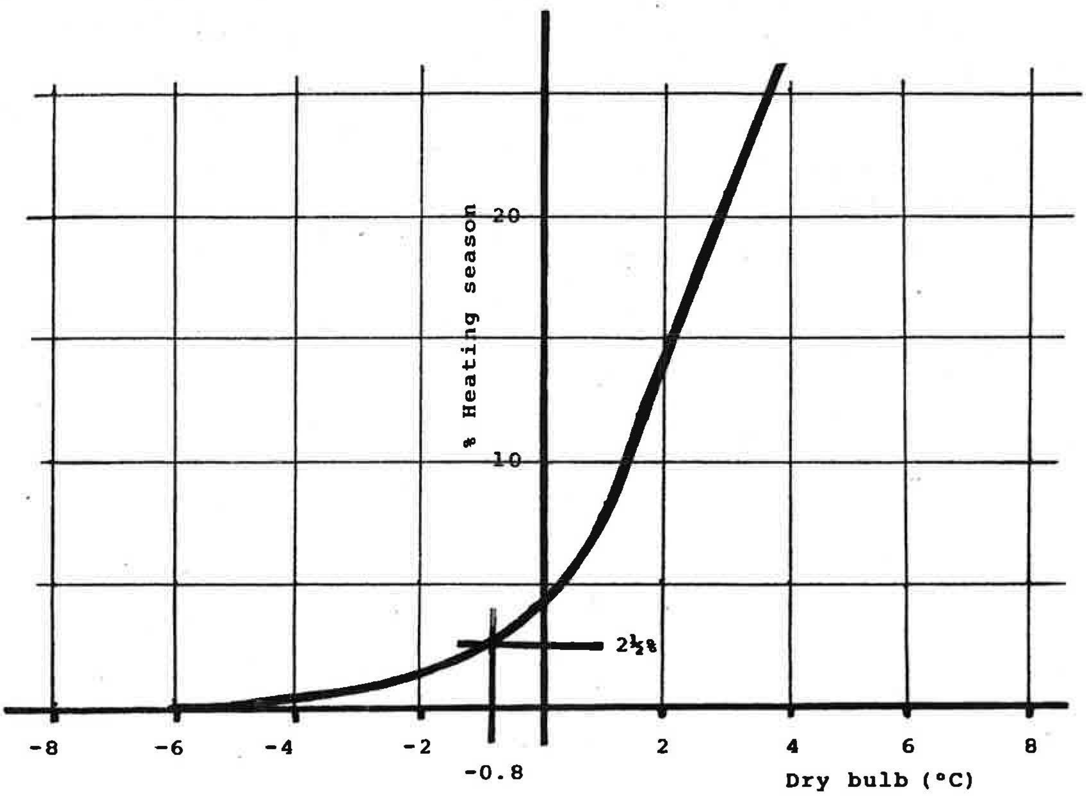

FIG 1. SIMPLE SELECTION OF DESIGN TEMPERATURE

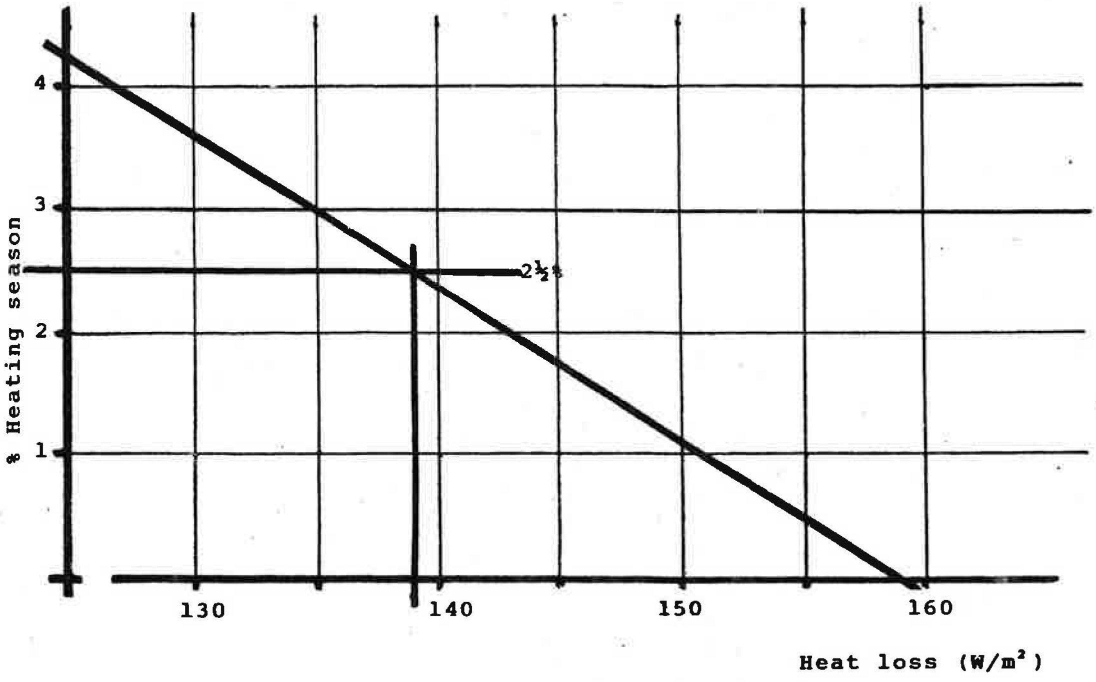

FIG 2. ROOF HEAT LOSS

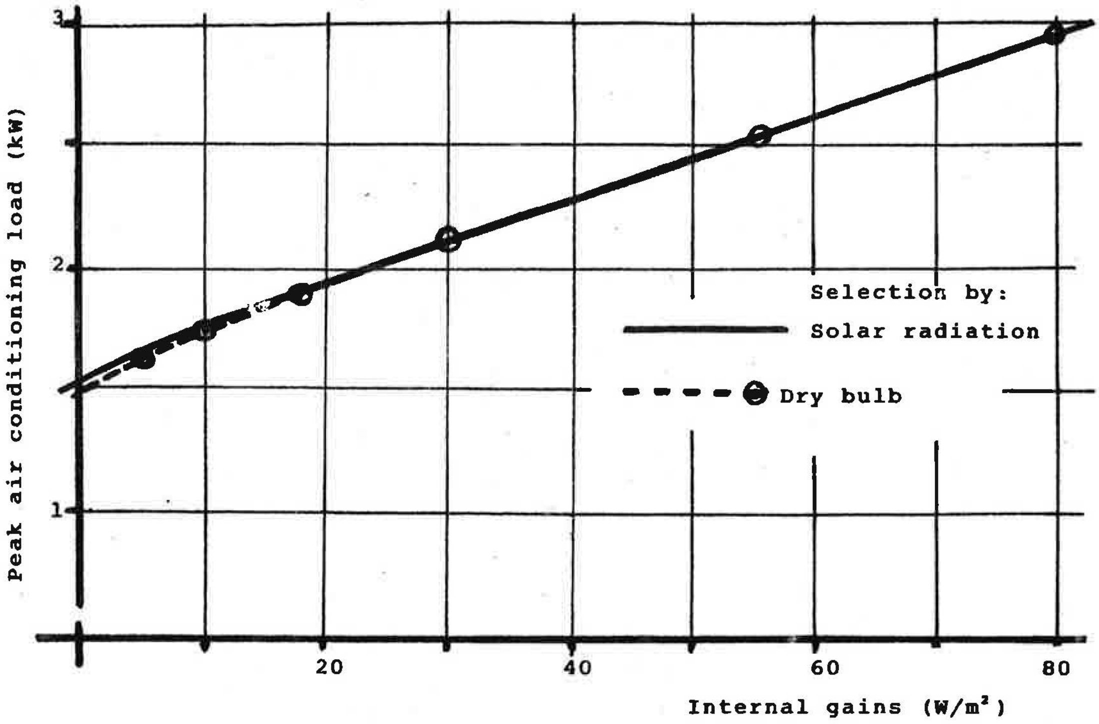

FIG 3a. PEAK AIR CONDITIONING LOADS FOR UNSHADED OFFICE

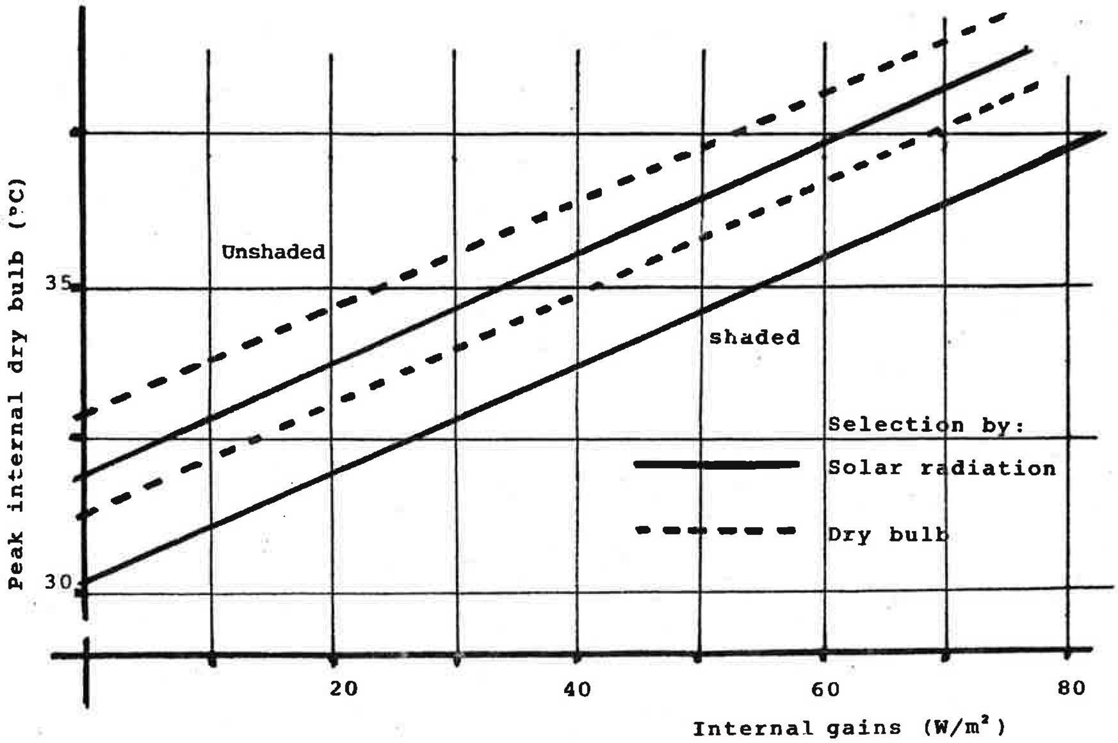

FIG 3b. PEAK INTERNAL TEMPERATURE

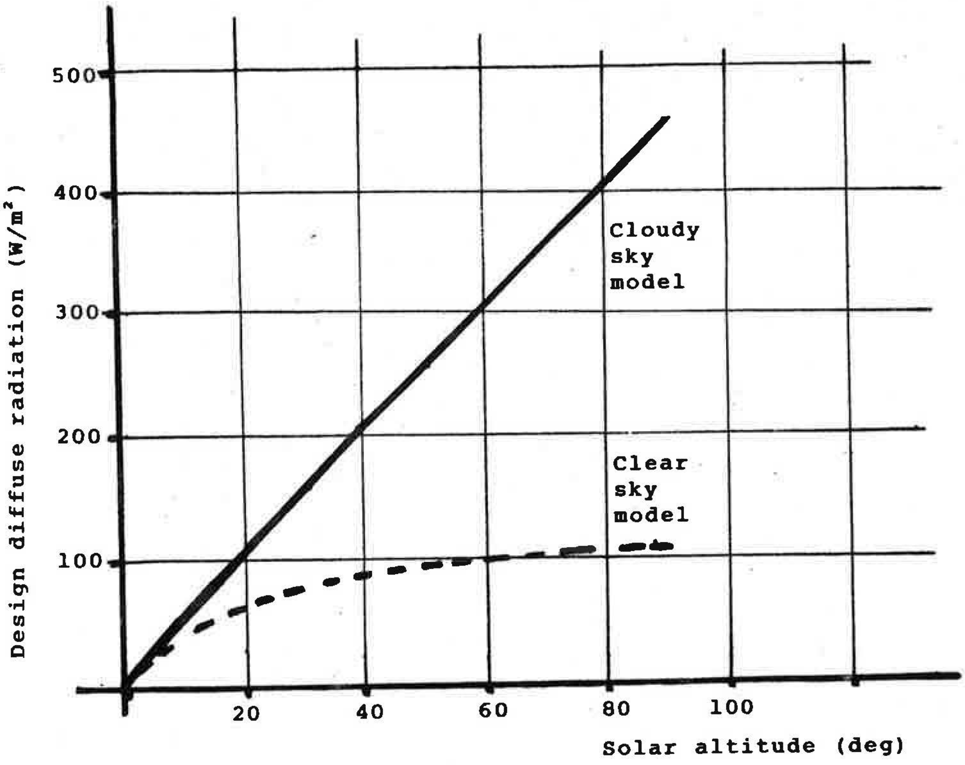

FIG 4. DIFFUSE RADIATION MODELS