LET'S TALK ABOUT THE WEATHER

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In this paper the availability of weather data in Australasia in terms of both hourly data for energy simulations and synthesized design day data for cooling and heating load estimation is discussed. Problems in establishing suitable data as identified in recent and current work carried out by ACADS and others, together with some possible solutions are discussed. A method of extrapolating energy consumption estimates to locations where hourly climatic data is not available is presented. The possible use of energy simulation programs in an iterative mode to size heating and cooling plant is also discussed.

Introduction

A number of building analysis/simulation computer programs that require weather data as input are now available, and being widely used, in Australia. These include programs estimating the heating and cooling capacity of air conditioning plants, the performance of solar heating systems, and for estimating the energy consumption and performance of buildings and their services.

For heating and cooling load estimation, design outdoor dry bulb and wet bulb temperatures and solar radiation data at each hour that the load calculations are required to be carried out, have to be established (i.e. a set of monthly "design days" is required). This data can be derived from hourly meteorological readings or where such is not available, from daily 3 pm recordings.

For solar heating system selection, average monthly solar radiation data and dry bulb temperature data is normally required, although hourly data for a full year is required for the more comprehensive analysis programs.

For energy simulation programs, hourly weather data for a number of full years is required.

In most countries throughout the world, meteorological data is recorded in a representative number of locations.

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Often however, this data is recorded only at either 3 hourly interval, or, in many instances, only twice daily (9 am & 3 pm). Hourly data is therefore in many cases not readily available. In addition, in most countries solar data is only recorded in a small percentage of the meteorological recording stations, e.g. there are over 800 locations where 8 am and 3 pm data is recorded by the Australian Bureau of Meteorology (including locations in Papua New Guinea and some nearby islands). Of these there are 90 stations where data is recorded at 3 hourly intervals and only 34 where solar data is recorded. This is not untypical of many other countries.

Data Needed for Air Conditioning Load Calculations

The ASHRAE Method

For air conditioning load calculations, ASHRAE (ASHRAE Fundamentals 1989) tabulate for locations throughout the USA and for a number locations in other countries:

- for cooling: the dry and wet bulb temperatures that are equalled or exceeded by 1%, 2.5% and 5% of the total hours during the months of June through September in the Northern Hemisphere, and the months of December through March in the Southern Hemisphere. The coincident wet bulb temperature (being the mean of all wet-bulb temperatures occurring at the specific design dry bulb temperature), is also listed.

- for heating: the dry bulb temperature that is equalled or exceeded by 99% or 97.5% of the total hours during December through February in the Northern Hemisphere, and June through August in the Southern hemisphere.

These outdoor design conditions are derived from hourly data and are taken as the design conditions at 3 pm July in the Northern Hemisphere and 3 pm January in the Southern Hemisphere. To these, temperature corrections based on yearly range (for monthly variations) and daily range (for hourly variations in each design day) are applied to provide a "design day" in each month.

For solar loads computer calculated design day hourly values are generally used.

The AIRAH/ACS Method

Within Australia (including some of the nearby islands) there are only 78 recording stations where sufficient three hourly surface data is available. Of the 34 locations where solar data is measured there are only 26 where global and diffuse solar radiation is measured. It was not until 1983 (Walsh, Munro and Spencer) and more recently in 1990 through the work of Delsante, that a climatic data bank of hourly surface and solar data for these 78 locations was established and made available. This hourly data was established by interpolating recorded three hourly surface data as described by Walsh et al and using recorded cloud cover to estimate solar irradiance (Moriarty 1991).

Prior to this in 1973 in the absence of hourly data (as required in the ASHRAE methodology) in all but a few locations throughout Australia, the Australian Construction Services devised an alternative method for evaluating design conditions for air conditioning load calculations based on available 3 pm data. In this method, for non critical and comfort process installations, the daily 3 pm temperature readings are interrogated for a period of up to 10 years and a 3 pm January summer design temperature chosen which is exceeded on average on only 10 days per year, allowing for one standard deviation - (AIRAH/ACS 1988). With this method the dry bulb and wet bulb temperature are evaluated independently. The reasons why coincident wet bulb temperatures are not used, has not as far as the authors can ascertain, been documented, but is probably because when using 3 pm readings only, there is insufficient data to establish reliable and representative coincident data. The use of independent dry and wet bulb data is conservative but, as shown by Mason, (Delsante & Mason 1990), generally only increases cooling loads by about 2% - 3%.

For critical cooling processes hourly data for a number of years (for the 18 locations where such data could be obtained from the Australian Bureau of Meteorology) was analysed. The critical design conditions were established on the basis of the dry and wet bulb temperatures which are exceeded on 0.25% of the plant operating hours.

In 1990 Delsante, (Delsante & Mason 1990) in establishing hourly data for the additional 60 locations throughout Australia also expanded the list of locations for which the 10 day per year 3 pm outdoor comfort and critical design conditions was available to 678 and 78 respectively and this was subsequently published by AIRAH, (AIRAH/ACS 1992).

To these 3 pm design conditions, corrections based on yearly range and daily range are then applied (as typified in Table 2 and 3 in the AIRAH/ACS Application Manual DA9) to establish hourly values for a design day in each month.

For heating, 8 am temperatures are interrogated in a similar way to that for cooling design conditions with the criteria for comfort process installations being the 8 am temperature exceeded, on average, on not more than 10 days per year whilst for critical processes the criterion of 0.25% of the plant operating hours is used.

For solar loads tabulated maximum solar heat gain values as a function of latitude, month and exposure are used. These values are then multiplied by factors to take account of the storage effects of the space being conditioned.

Data Needed for Energy Calculations

For the estimation of energy consumption in buildings actual hourly dry bulb and wet bulb temperatures and direct and diffuse solar data is required. Even if a particular computer program uses binned weather data, complete hourly data is required for a number of years to establish this binned data.

The Problems and Some Solutions

To establish weather data in a format suitable for use in air conditioning load estimation and building energy simulations, it is desirable to have data available on computer media. As countries like Australia expand their capabilities, and extend their area of operation to neighbouring countries, there is a need to establish appropriate weather data in a format suitable for these programs.

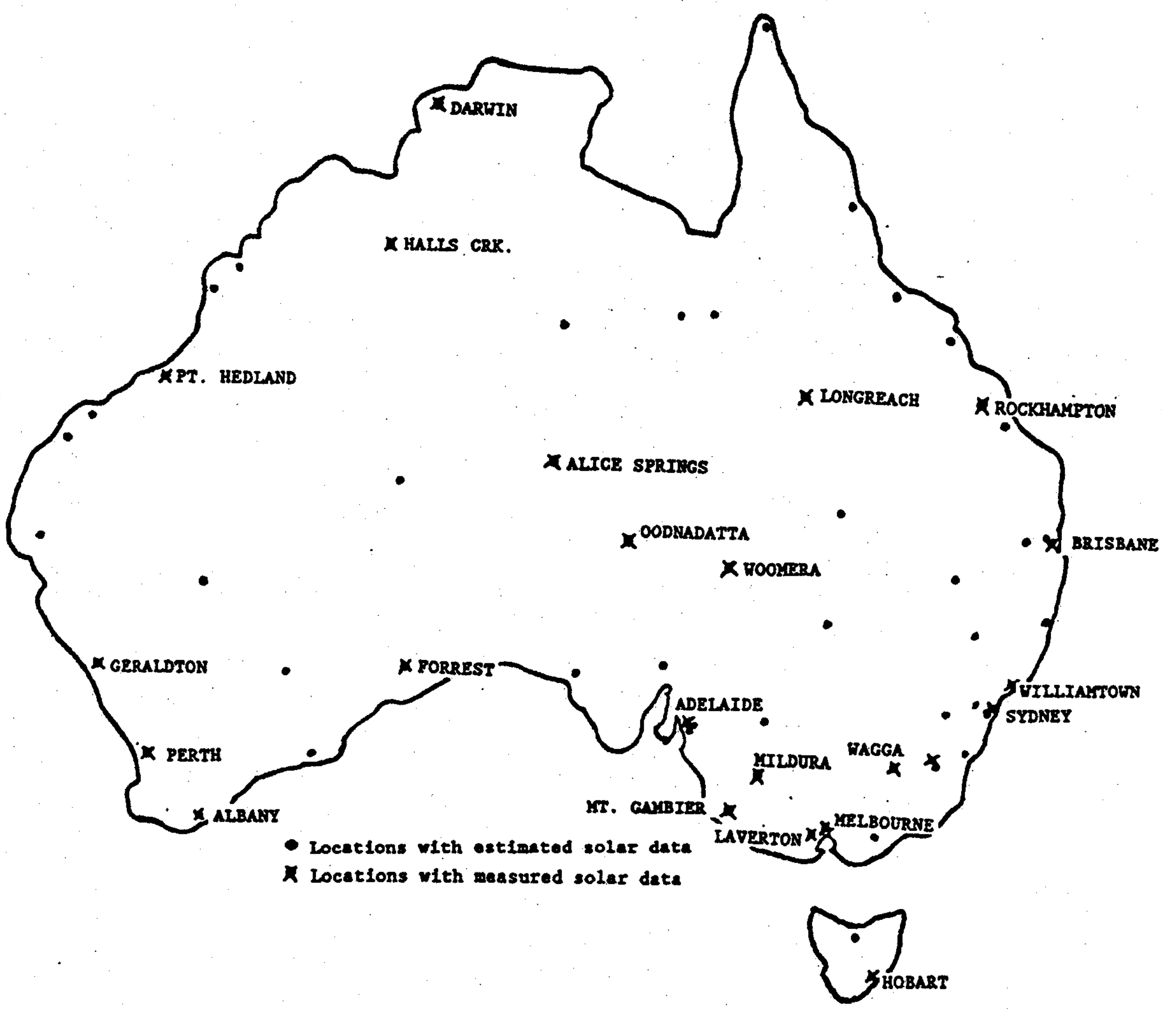

Fig 1 Location in Australia where Measured and Estimated Solar Data is Available

The first problem that is encountered in doing this is that in some countries the only available raw weather data is in hand written hard copy format.

Hourly Data - for Energy Simulations

Looking now at the particular, and first at the availability, of hourly data for energy simulation, it can be stated that although surface data is readily available for many locations in the majority of countries around the world either -

(a) no solar data at all is recorded
(b) solar data is only recorded in a small percentage of the locations where surface data is recorded
(c) the solar data that is recorded is often only the total radiation whereas total and direct or diffuse is needed.
(d) for many locations only three hourly surface data is available.

Some solutions to these problems are however available, viz:

(i) Solar irradiance can be estimated using a method based on observations of cloud cover at three levels and other standard measurements (Moriarty 1991). This has been done in Australia for 56 locations and Fig 1 indicates the locations in Australia where measured solar data and estimated solar data is available.

Table 1 lists statistical data on a comparison of measured solar data and estimated data for Darwin Airport (1978 and 1979) and Melbourne (1979). As can be seen from Table 1 there is considerable variation between the measured and estimated data. On modelling a particular hypothetical office building located at the Darwin Airport however, it was found that the estimated energy consumption using the estimated solar data, was only 2% different (higher) than that obtained when using the measured data.

(ii) ASHRAE (ASHRAE Fundamentals 1989) states that "Data from many specific weather stations can supply a data base for interpolation of the expected conditions at nearby locations lacking data" and references Crowe L W as a source for interpolation criteria.

(iii) ACADS has correlated heating energy consumption against heating degree days and cooling energy consumption against a cooling base temperature for all locations in Australia where hourly data is available. The results of this correlation are presented in Fig 2 and 3. The cooling base temperature is the summer comfort 3 pm design wet bulb temperature plus 10% of the summer design comfort dry bulb temperature.

This work is an extension of work carried out by ACADS for the NSW Public Works in the production of their Building Energy Manual (PWD NSW 1993) wherein the energy consumption of a typical 5 storey office building was estimated using the ACADS version of the APEC building energy estimation program ESPII to determine a correlation of energy consumption to location.

The building was modelled in turn in each of the 78 locations where hourly weather data was available. A reasonable correlation between

	Solar Radiation		
	Global	Diffuse	Direct
Melbourne 1979			
Mean Deviation	6	-20	60
Standard Dev	95	52	173
Max Variation	*490	284	847
Darwin Airport 1978			
Mean Deviation	52	-67	195
Standard Dev	136	72	230
Max Variation	*705	328	*1228
Darwin Airport 1979			
Mean Deviation	58	-68	202
Standard Dev	132	72	219
Max Variation	626	330	*947

* indicates measured values higher than estimated.

Table 1 Comparison of Measured and Estimated Solar Data for Darwin and Melbourne (W/m^2)

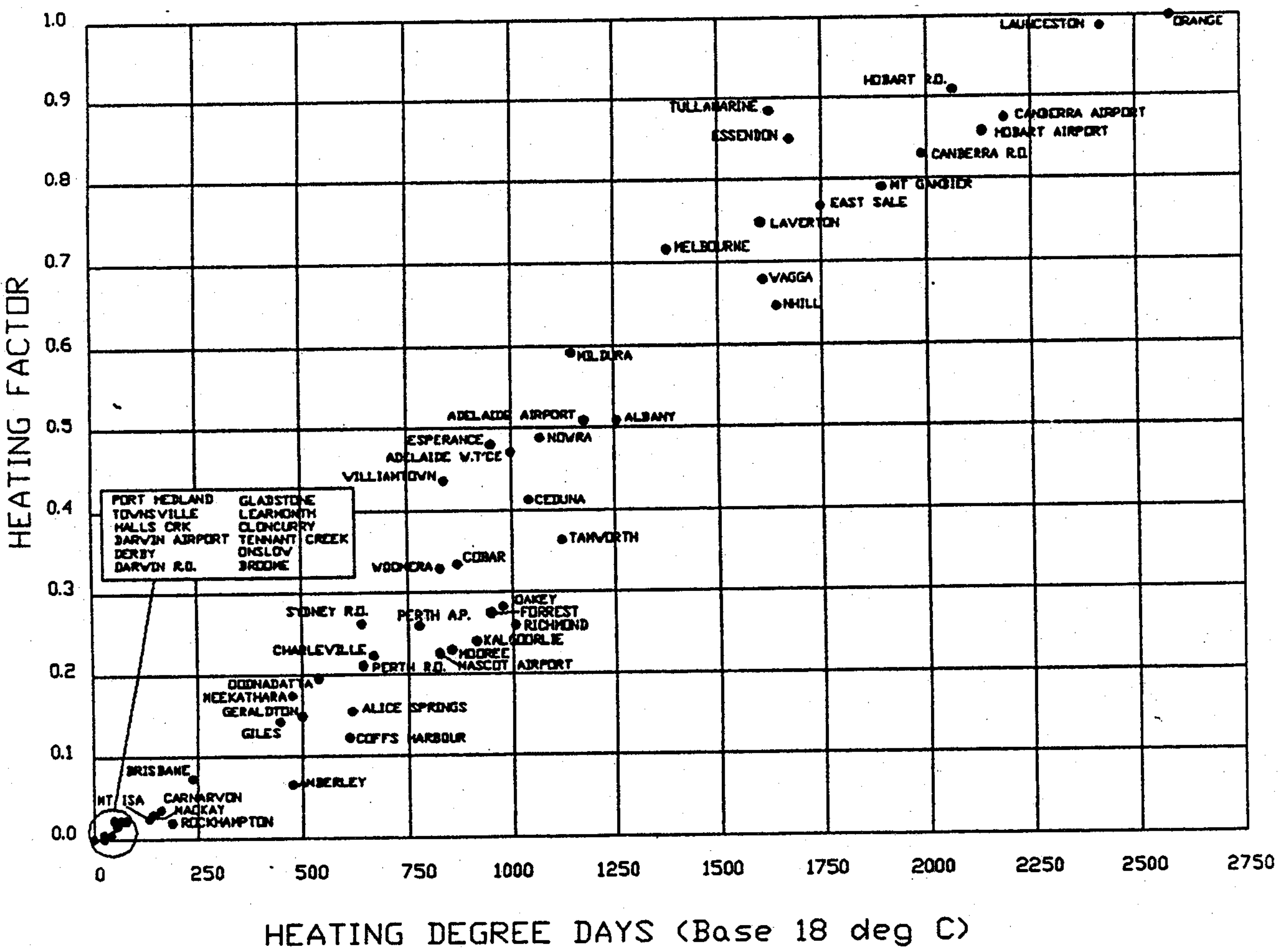

Fig 2 Heating Energy Consumption of a Typical Office Building versus Heating Degree Days

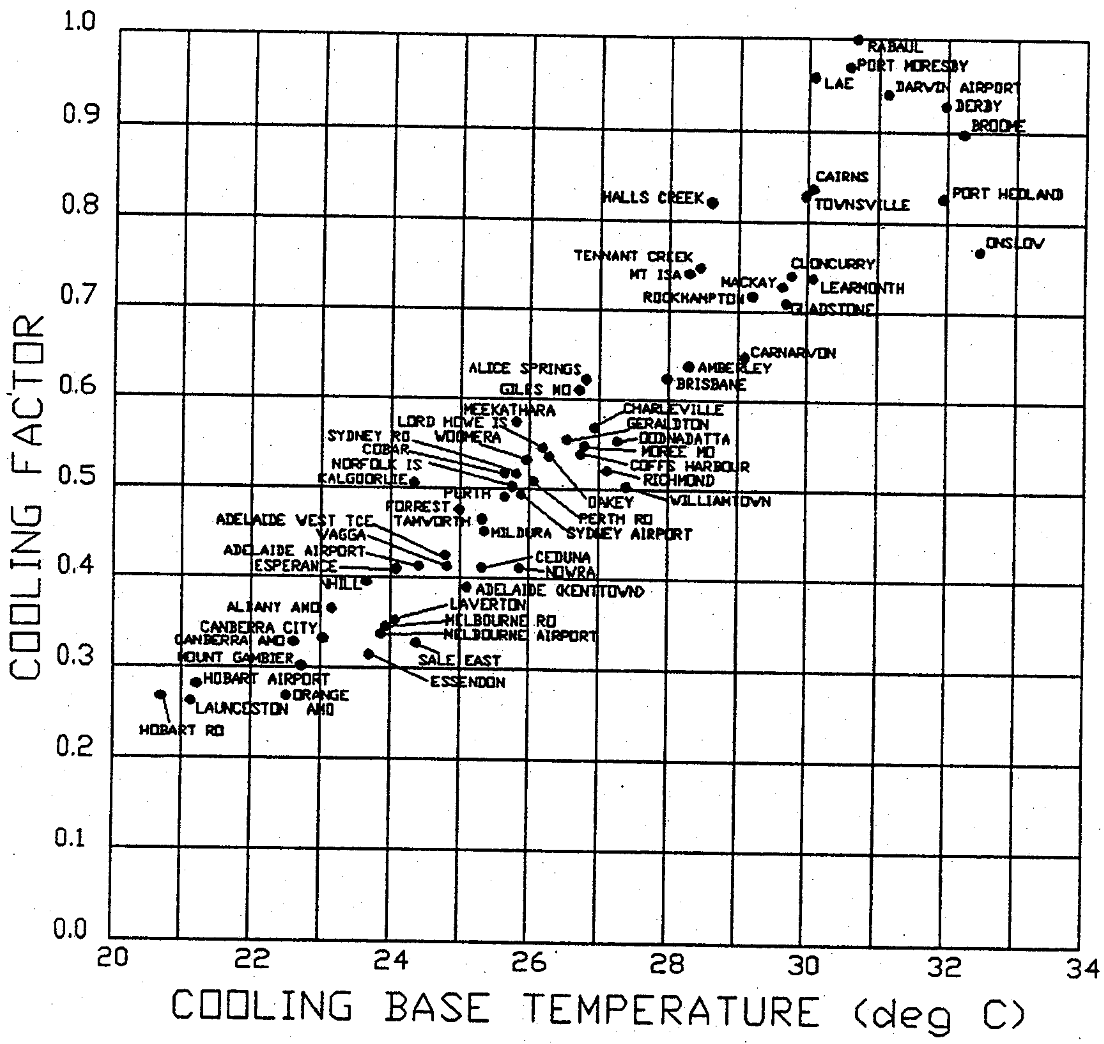

Fig 3 Cooling Energy Consumption of a Typical Office Building versus Cooling Base Temperature

cooling energy consumption and the cooling base temperature as defined above was found but it is considered that the inclusion of a solar component in the formulation (e.g. the average solar radiation level) may have improved the correlation.

From the values of heating degree days, and cooling base temperature for a given location, interpolated or extrapolated values of the heating and cooling energy, consumption can be obtained by either:

- using weather data for 2 nearby locations where hourly data is available and then interpolating on the basis of heating degree days for the heating energy and cooling base temperature for the cooling energy consumption, or
- using the weather data from a nearby single location in an energy simulation and factoring the heating and cooling energy using Figures 2 and 3.

Design Day Data - For Cooling & Heating Load Estimation

The problems in establishing design day outside temperature data are not, as in the case of energy simulations, so much in the spread of locations where data is available (although this does become a problem with some of the solutions to some of the other problems that are identified) but more related to the appropriateness of the alternative methodologies used in establishing the values that should be used each hour of the day in each month. The problems are:

(a) In 1988 Mason and Kingston (Mason & Kingston 1988) concluded that corrections based on yearly range (as used by ASHRAE and AIRAH) were not location specific enough and that those in the AIRAH/ACS Application Manual DA9 originally developed by the Carrier Air Conditioning Co. are in many instances far too conservative particularly in the mid seasons where peak loads often occur on northerly aspects. A method whereby 3 pm temperature data is interrogated and a temperature each month that is not exceeded on average over a number of years on more than 1 day per 2 years was developed and is now in use in Australia. The 3 pm January design temperature based on the 10 day per year criterion is used (for comfort applications) where it is lower than the 1 day per 2 years criterion but when it is not the 1 day per 2 year criterion is used in lieu of the corrections based on yearly range. Dry and wet bulb temperature data based on this method has now been incorporated in the computer programs CAMEL and TEMPER which are used extensively in Australia.

(b) Because the criterion for critical air conditioning processes is based on interrogation of hourly data (the .25% criterion described above), there are generally only a few locations (78 in Australia) where critical conditions can be established. In 1992 Mason (Mason 1992) proposed an alternative wherein the temperatures based on the one day in two year criterion are used to establish the 3 pm critical dry bulb and wet bulb temperatures to be used in each month. In this work, it was concluded that there would generally be very little difference in the calculated cooling loads if this alternative was adopted, the advantage being that critical conditions can then be established for any location where 3 pm data is available (678 locations in Australia).

(c) In recent unpublished work carried out by ACADS for AIRAH it was established that in a number of locations in Australia the 3 pm design conditions are not the maximum design conditions. In Carnarvon in Western Australia for example, because of a regular afternoon wind condition (known further South as the Fremantle Doctor) it is well established that the noon dry bulb temperature in January is generally 4° to 5°C hotter than the temperature at 3 pm (refer Fig 4). Further it was discovered that this type of temperature variation occurs in other locations even on the other side of the Continent.

Furthermore by interrogating hourly data, (for a number of locations where such data is available), a plot of dry bulb temperatures at each hour of each month that is not exceeded more than once in two years, can be made and compared with values established by plotting the corrected 3 pm values based on the daily range. These are presented in Fig 4 and it can be seen that the correlation is poor and in many instances the design temperatures based on the traditional daily range corrections are at considerable variance.

Hourly design wet bulb temperatures established on the basis of the values not exceeded more than once in two years and those based on the daily range corrections for Melbourne and Carnarvon are plotted in Fig 5. As in the case of the dry bulb values the correlation is poor. Some computer programs make the assumption that the moisture content of the air stays relatively constant over the period of a day. Values based on this assumption are also plotted in Fig. 5. This only adds a further dimension to the problem.

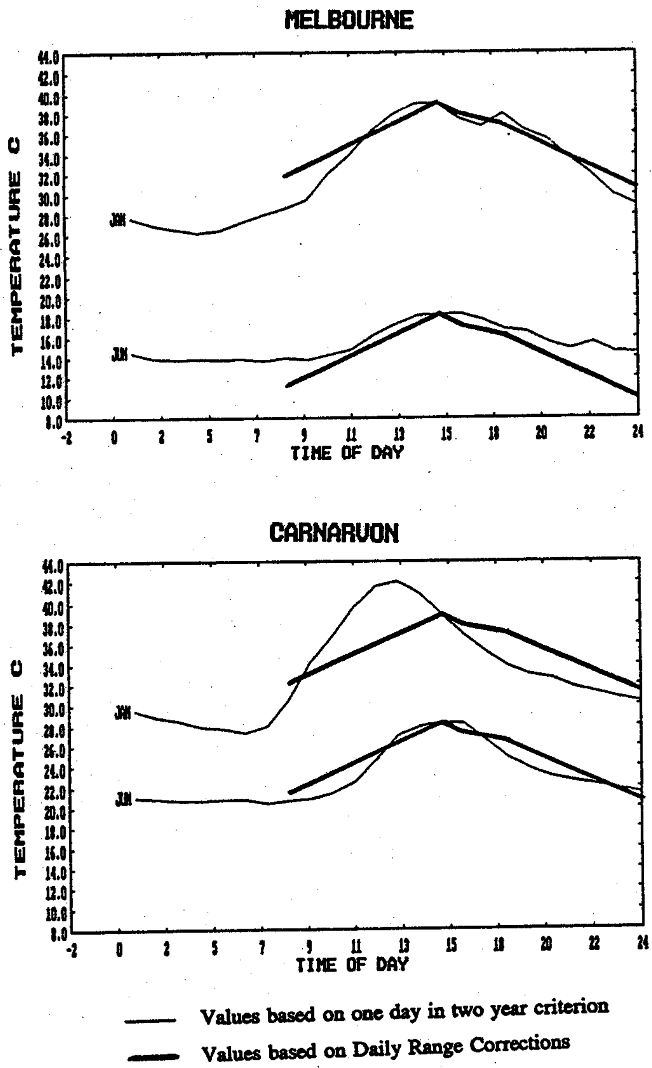

Fig 4 One Day in Two Year Hourly Dry Bulb Design Temperature Compared to Corrected Values Based on Daily Range

It might be concluded that the daily range corrections applied to the 3 pm temperature to obtain hourly values are inappropriate but what we are dealing with here is a hypothetical design day and it is difficult to establish which values are "correct". It should be noted however that the values based on the one day per two year criterion are more location specific and hence more likely to reflect local variations.

If, however, one accepts the values established using the one day in two year criterion at each hour, a new problem arises in that these values can only be established for locations where hourly data is available. One way around this problem (yet to be thoroughly investigated) is to set up the hourly data as a series of corrections to the 3 pm January temperatures for each location where hourly data is available and then proportion these

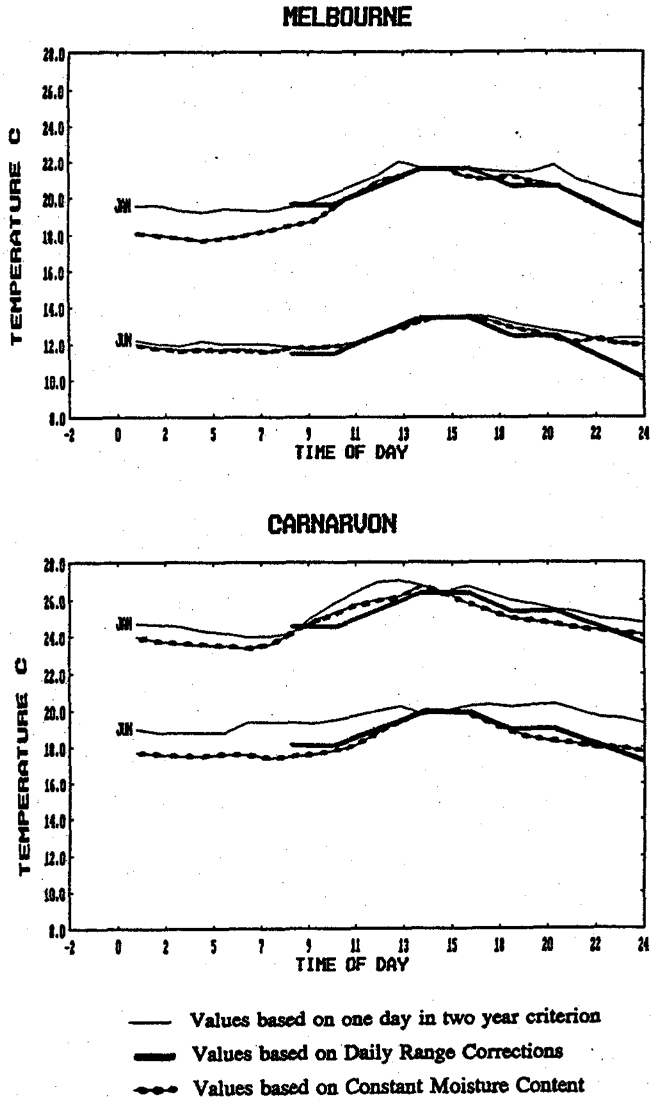

Fig 5 One Day in Two Year Hourly Wet Bulb Design Temperatures compared to Corrected Values Based on Daily Range and Values Based on Constant Moisture Content.

on the basis of the daily range for the particular location where only 3 pm data is available e.g. for a building in Victor Harbour the corrections for Adelaide factored by the ratio of the respective values of daily range could be used.

Thus far we have only discussed dry and wet bulb temperatures. With solar data the problems are similar, but in the authors view, far less likely to be resolved. Monthly peak or design day hourly solar gains based on clear sky conditions, are normally used in estimating cooling loads. These peak solar gains are based in terms of geographical location on latitude only and hence the peak solar gain for instance in Sydney with a latitude of 33°52' is 372 W/m^2 and in Tamworth with a latitude of 31°05' is 6.5% lower (348 W/m^2) The average daily global radiation however for Sydney in January is 22.3 MJ/m^2 and for Tamworth it is 25.1 MJ/m^2, i.e. 12.5% higher.

In locations where smog and haze is consistently in existence, a haze correction may be applied. Whatever haze or sky condition that is assumed however, is usually assumed to apply equally at all hours of each design day in each month and this in many locations must be far from realistic and would often lead to overdesign particularly in zones where the peak load does not occur in January.

Using Energy Simulation Programs to Size Air Conditioning Plant

There would appear to be no conclusive answers to the problems of establishing hourly design day dry and wet bulb and solar conditions for air conditioning load estimation. On the other hand there is now a reasonable number of locations in Australia where hourly data is available for energy estimations. The methods proposed above, interpolating on the basis of heating degree days and cooling base temperature, also provide a reasonable method of estimating energy consumption in many other locations.

In a new building design establishing the capacity of the air conditioning plant is an important design task and will impact the energy consumption of, and the comfort level in a building. A lot of time and energy could be devoted to revising further the methods of establishing design conditions to be used each hour in load estimation programs. With the rapidly increasing power of micro computers since their inception in the early 1970's and the first Australian PC in 1982, the question must now be asked -

Could energy simulation programs that use actual hourly weather data be made to iterate the cooling and air handling plant capacities on the basis of the number of hours that the inside temperature lies outside the thermostat range during the hours of plant operation?

Most energy simulation programs list this information and existing programs could therefore be used currently to manually iterate to a solution whereby the coil, chiller, boiler, and air handling plant capacities can be set so that each space temperature will exceed the thermostat range on no more than 1%, 2.5% or 5% of the total plant operation as required. Five years ago processing time precluded this but now with micro computing processing time being reduced by factors of 40, 50 and even more, such a process is now a distinct possibility and could well be automated in the energy simulation programs thereby obviating the need for cooling/heating load estimation programs.

A worthwhile exercise would be to model a typical building located in each of the 78 locations where hourly weather data is available and compare the number of times the temperature lies outside the entered thermostat range. The cooling and heating coil, fan, chiller and boiler capacities could be estimated using a program like CAMEL and then these quantities fed into an energy simulation program such as ESPII. The results would indicate whether the load estimation program over or under estimates the plant capacities in each location (provided of course that the model in the energy simulation program is "correct").

Conclusion

The object of this paper has been to highlight problems associated with air conditioning design tasks that utilise weather data and to stimulate further discussion and research in this area.

Some distinct problems with current methods of establishing design conditions for estimating air conditioning cooling loads and air quantities have been identified. Some partial solutions have been proposed but because of the nature of the task no conclusive solutions could be found. Indeed the limited accuracy of A.C. load estimation programs in terms of practical plant sizing (as often re-iterated by those who believe computer programs only create illusions of accuracy when used for this particular task) has been re-affirmed.

A method for interpolating energy estimates between locations where hourly data is available and where heating degree day and 3 pm design conditions are available is however proposed.

The possibility of using energy simulation programs for establishing A.C. plant capacities by a process of iteration has also been discussed.

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