Comfort and Critical Design Conditions – Air Conditioning Load Estimation

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OUTDOOR DESIGN CONDITIONS FOR AIR CONDITIONING LOAD CALCULATIONS

When estimating cooling and heating loads for buildings, ambient outdoor design dry-bulb and wet-bulb temperatures are needed to allow the load estimator to calculate:

1. Sensible conduction loads through the building fabric (walls, windows and roofs).
2. Sensible and latent load due to any outdoor air introduced into the building.
3. Sensible and latent load due to infiltration of outdoor air into the building.

Several data sets are available to load estimators for this purpose, including the ASHRAE worldwide data set (ASHRAE Fundamentals 2013), which is based on percentage exceedance (or hours of exceedance per month), and the Australian Critical/Comfort data set, which is based on an exceedance of one day in two years for critical conditions and an exceedance of 10 days per year for comfort conditions.

This paper outlines the basis of the Post-1990 and Pre-1990 Australian Critical/Comfort data sets, and provides information on how to interpret the information in the two Critical/Comfort outdoor design conditions spreadsheets.

This data in the spreadsheets has been developed, checked and formatted by ACADS-BSG based on climatic data provided by Exemplary Energy, the Australian Bureau of Meteorology (BoM) and the CSIRO. AIRAH acknowledges these organisations for their contributions to the development of these design condition data sets and their willingness to share that data.

Australian Critical/Comfort Post-1990 data set

The data listed in the Post-1990 Critical/Comfort data set comprises design conditions:

1. For more than 800 locations around Australia.
2. Based on climatic data within the range 1990 to 2013 obtained from the Australian Bureau of Meteorology (BoM).
3. For the pre-1990 locations where the BoM is still recording climatic data.
4. For additional locations where the BoM is now recording climatic data, including new locations and locations where the BoM has moved the recording station, e.g. from the local post office to the airport or to where automatic weather stations (AWS) have been installed.
5. Based on 3pm data for summer design conditions and 8am data for winter design conditions, extracted from available hourly data or 9am and 3pm data where hourly data was not available.
Notes on Post-1990 and Pre-1990 “Comfort” and “Critical” outdoor design condition data sets
Since 1994 there has been an increase in the number of sites where complete hourly climatic data is available. Exemplary Energy now has hourly data (primarily developed for use in energy simulations) for 200 locations. This hourly data was sourced from the BoM and thoroughly checked for consistency and missing data. BoM has also introduced a number of Automatic Weather Stations (AWS) which measure hourly temperature data, although many of these have a large number of hours with missing or incomplete data, including some sites that do not record wet-bulb temperatures.

The updated design temperatures in Critical/Comfort Post-1990 data set were calculated from the hourly data supplied by Exemplary Energy where available, or else from the 9am and 3pm data supplied by the BOM. The Critical/Comfort Post-1990 data set includes approximately 350 locations where hourly temperature data is available, and a further 450 locations based on 9am and 3pm data, where hourly data is not available.

With the 9am and 3pm data from the BOM, because 8am temperatures rather than 9am temperatures are required for the calculation of the winter design conditions in accordance with AIRAH DA09, an adjustment was made to the 9am temperatures and this was done using the average minimum temperature for the location (supplied by BOM).

The BoM is no longer recording temperature data at some of the locations listed in the third edition of DA09. Some have been replaced by AWSs in slightly different locations, while others have been moved from, for example, the local post office to the airport. This can result in noticeable changes in the design conditions, which can be more significant than the use of the more recent data. For this reason the design conditions for these locations have been retained in the Critical/Comfort Post-1990 data set (identified by the years of data listed). Hence, there are 872 locations with design conditions listed in the Critical/Comfort Post-1990 data set.

Critical/Comfort pre-1990 data set
The data listed the pre-1990 Critical/Comfort data set comprise design conditions:

1. For more than 570 locations around Australia, New Zealand, and South-East Asia, and a number of other overseas locations.
2. Based on 1970–1980s climatic data (for a range of up to 10 years) obtained from the BOM and, for overseas locations, local meteorology bureaus.
3. Based on 3pm data for summer design conditions and 8am data for winter design conditions.

In 1982, when DA09 was first published, there were only 62 locations listed, with 17 locations where the BOM recorded hourly temperature data. The other 45 locations only had 9am and 3pm data, or in some cases three-hourly data recorded. The climatic data included in DA09 (Third Edition 1994) is for approximately 500 sites and was calculated by the BoM under contract to the CSIRO using data for the period 1970 to 1988.
Notes on Post-1990 and Pre-1990 “Comfort” and “Critical” outdoor design condition data sets

Data provided in each spreadsheet

The design conditions listed in both Excel spreadsheets comprise the following:

- **Column A**: BoM Weather Site Number
- **Column B**: Weather Site Name
- **Column C**: Years of data used to establish the design conditions and a character in brackets, indicating whether the climatic data used to determine the design conditions was (H) hourly data or (3) 3pm and 9am data only.
- **Column D**: Annual non-coincident 3pm cooling “comfort” design dry-bulb temperature – the 3pm dry-bulb temperature that is individually exceeded on not more than 10 days per year (inclusive of one standard deviation).
- **Column E to P**: Monthly 3pm “critical” cooling design dry-bulb temperatures. The cells with the yellow fill are the temperatures that need to be replaced by the value in column D to generate the monthly 3pm “comfort” DB design conditions.
- **Column Q**: Annual non-coincident 3pm cooling “comfort” design wet-bulb temperature – the 3pm wet-bulb temperature that is individually exceeded on not more than 10 days per year (inclusive of one standard deviation).
- **Column R to AC**: Monthly 3pm “critical” cooling design wet-bulb temperatures. The cells with the yellow fill are the temperatures that need to be replaced by the value in column Q to generate the monthly 3pm “comfort” WB design conditions.
- **Column AD**: Average daily range for January. This is used in conjunction with the corrections listed in DA09 to determine the hourly temperatures each side of 3pm for the design day in each month.
- **Column AE**: Heating design dry-bulb temperature – the 8am dry-bulb temperature exceeded on no more than 10 days per year (inclusive of one standard deviation).
- **Column AF**: Heating design relative humidity – assumed as 80%.
- **Column AG**: Site latitude.
- **Column AH**: Site longitude.
- **Column AI**: Site reference longitude.
- **Column AJ**: Site elevation in metres.

The monthly comfort design conditions are the lesser of the monthly “critical” conditions and the annual comfort cooling design condition.

The dry and wet-bulb temperatures listed are the non-coincident design temperatures to enable the maximum cooling sensible load and the maximum cooling latent load to be calculated in the one run of a load estimation computer program (such as CAMEL).

**Basis of the Critical/Comfort data sets**

**Basis of Calculation of Summer Design Conditions**

The monthly “critical” design conditions are the non-coincident dry-bulb and wet-bulb 3pm temperatures that are individually exceeded on an average of one day in two years.
Notes on Post-1990 and Pre-1990 “Comfort” and “Critical” outdoor design condition data sets

The “comfort” design conditions are the non-coincident dry-bulb and wet-bulb 3pm temperatures that are individually exceeded on 10 days per year (inclusive of one standard deviation).

The monthly comfort design conditions are the lesser of this value and the “critical” monthly temperature.

The non-coincident temperatures are listed to enable the one calculation to be used to determine the maximum cooling sensible load and maximum cooling latent load.

**Basis of Calculation of Winter Design Conditions**

The winter “comfort” design condition is the 8am dry-bulb temperature that is not exceeded on 10 days per year (inclusive of one standard deviation).

**Application of the Design Conditions**

It is important to distinguish between the empirically derived design conditions provided in these data sets, which are needed for estimating air conditioning loads for plant sizing, and the actual measured hourly data or the averaged monthly hourly data (reference metrological years – RMY) that are required for estimating the energy consumption of a building or facility. Energy simulation programs use hourly climatic data (from an actual or an “average” year of climatic data) and predicted building operational characteristics to calculate the estimated energy consumption of the building or system.

The empirical design conditions provided in these Critical/Comfort outdoor design conditions data sets, although based on hourly temperature data, cannot be used for estimating the energy consumption of a building.

**ASHRAE Design Conditions for Australian Locations**

ASHRAE has calculated design conditions for approximately 350 locations in Australia using temperature data recorded from 1990 to 2012 by the BOM primarily at its AWSs. ASHRAE design conditions are only available for sites where hourly data is recorded. The ASHRAE data for each location comprises a range of climatic data. However, of interest to designers undertaking load calculations are the monthly 3pm design conditions. This data comprises sets of 12 monthly dry and mean coincident wet-bulb temperatures and sets of monthly wet and mean coincident dry-bulb temperatures that are not exceeded for 0.4, 2.0, 5.0 and 10% of the time.

It has been suggested that the ASHRAE 0.4% figures are roughly equivalent to the Comfort conditions. If this is true then there are no equivalent ASHRAE values to the Critical conditions.

**Provenance and Quality Control**

The revised Comfort/Critical monthly design conditions were calculated by ACADS-BSG Pty Ltd for use in the air conditioning load-estimation program CAMEL and other similar load-estimation programs that may be able to use this data.
Notes on Post-1990 and Pre-1990 “Comfort” and “Critical” outdoor design condition data sets

A computer program based on the original computer program developed by the CSIRO when the original design conditions were first introduced into DA09 was used to calculate the revised design conditions. The results from these calculations were compared manually with the design conditions currently listed in DA09.

The revised design conditions in the Post-1990 Critical/Comfort data set are based on:

1. Hourly recorded data from 1990 to 2012/13 originally obtained from the BoM where such data was available (200 locations) by Exemplary Energy Pty Ltd, which then rigorously interrogated and validated this data ensuring there was no missing or spurious recordings, or
2. Where hourly data was not available (a further 672 locations), on 3pm and 9am recorded data from 1990 to 2013 obtained from the BoM. The required heating 8am design conditions had to be extrapolated from the available 9am data.

The original design conditions in the pre-1990 Critical/Comfort data set included in DA09 (Third Edition 1994) for approximately 500 sites was calculated by the Australian BoM, under contract to the CSIRO, using data for the period 1970 to 1988.

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