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Letter to the Editor[1]

Richard Aynsley

Delta T Corporation, 2425 Merchant St, Lexington, KY 40511, USA
Corresponding author: Tel: 1 859 233 1271; Fax: 1 859 233 0139; E-mail: dick@bigassfans.com

Regarding **Modeling efficient building design: A comparison of conditioned and free-running house rating approaches** by Maria Kordjamshidi, Steve King, Robert Zehner & Deo Prasad, *Architectural Science Review, 50*(1), March 2007, 52-59.

This is an extremely important paper as it could be used to argue for better treatment of energy efficient, free-running housing in Australia under house energy rating schemes. The Australian Building Code provisions for energy efficiency and its associated home energy rating scheme have resulted in a majority of new houses being air conditioned, particularly in warmer climate regions of Australia (Miller & Ambrose, 2005). After a study of contemporary housing subdivisions in Queensland, including the numbers of air conditioned houses, Miller and Ambrose reported that in 2001 around 28% of dwellings were air conditioned. By 2004, this number had increased to 36% with the expectation of a further increase to 56% in 2005 (see Figure 1). They raised the question: "Is climatically inappropriate design a factor behind the increase in energy use for cooling in Queensland?"

The definition provided in the Kordjamshidi *et al* paper for *free running* includes the words "does not use any mechanical equipment to maintain or improve its indoor thermal condition." This is not the case at least in north Queensland, where protestations resulted in the benefits of ceiling fans being included in assessment of indoor conditions during summer conditions.

A typical 84 m^2 3-bedroom, brick veneer, slab-on-grade house with awning shaded windows and an insulated metal deck roof in Townsville (north Queensland, Australia) rated at 2 stars by NatHERS in the 1990s consumed 295 MJ/m^2 or 23.6 GJ per year in electrical energy representing production of 6,844 kg of CO_2. This is more than 10 times the energy used by an attic fan and about 100 times that by ceiling fans supplemented by natural ventilation from wind (Aynsley, 1997).

A similar uninsulated no-star house would consume around 350 MJ/m^2 or 28 GJ and produce 8,120 kg of CO_2 or 19% more than the 2-star version. A 4-star version of the house with better glazing etc would consume around 200 MJ/m2 or 16 GJ and produce 4640 kg of CO_2 or 32% less than the 2-star version. The same house with 6 ceiling fans operating at medium speed (40 watts) for 12 hours per day for 4 summer months (December through March in Australia) would consume approximately 0.2 GJ of electrical energy representing 58 kg CO_2. If natural ventilation by wind is not utilized and fans were operated 24 hours per day, this amount would be less than double as fans in the bedrooms

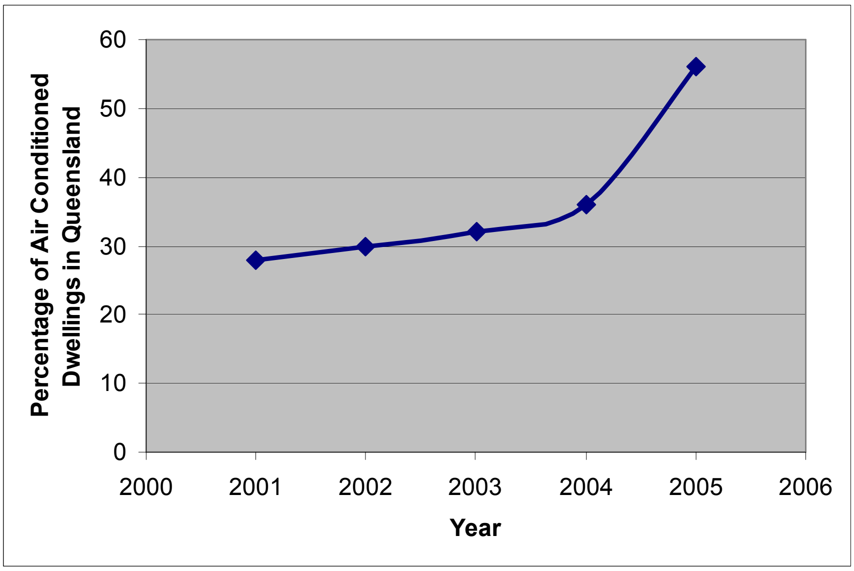

Figure 1: *Air conditioned dwellings in Queensland, Australia (after Miller & Ambrose, 2005).*

[1] This Letter to the Editor was submitted for consideration by Dr Richard Aynsley, former UNESCO Professor of Tropical Architecture, James Cook University, Australia, and a member of the Editorial Advisory Board of *ASR*. We are pleased to publish it and the comments in reply from the authors. The Editor welcomes similar scholarly Letters to the Editor commenting on previously published papers and the scientific issues they raise.

are likely to be used mainly in the evenings and fans in the living areas are unlikely to be operated all night.

From Table 4 in the Kordjamshidi *et al* paper, observations regarding the influence of insulation in the building envelope reflect the findings of a study by the University of Melbourne (1981). For a well ventilated, free-running house with more than 30 air changes per hour, the indoor air temperature is equal to outdoor air temperature. It takes only a few seconds for air to pass through the house. The function of envelope insulation in free running houses is to limit indoor surface temperatures to less than 4K above air temperature with an upper limit of 38°C. This prevents the surfaces becoming significant sources of radiant heat gain to occupants (Koenigsberger & Lynn, 1965). This is most important with respect to ceiling insulation as people are more sensitive to radiant heat from ceilings than other room surfaces (ISO 7730, 2005). The total thermal insulation needed for roof and roof space to ensure that ceiling temperature do not exceed air temperature by more than 4K under maximum sol-air temperature conditions can be calculated using Equation 2.

The temperature differences across each element in a low-mass multilayer roof are proportional to the thermal resistance of each element. For a given rate of heat transfer, the ratio of the total resistance of a roof construction to the temperature difference across the roof, $R_t / \Delta T_R$, is equal to the ratio of the resistance of the indoor air film under the ceiling to the temperature difference across the air film, $R_{iaf} / \Delta T_{iaf}$.

$$R_t / \Delta T_R = R_{iaf} / \Delta T_{iaf} \qquad (1)$$

This equation can be rearranged as:

$$R_t = \Delta T_R \, R_{iaf} / \Delta T_{iaf} \qquad (2)$$

By setting ΔT_{iaf} to 4Kso that the ceiling temperature is 4K above air temperature (outdoor air temperature) in the free running house, and setting ΔT_R as the peak difference between the sol-air temperature on the roof surface and indoor air temperature (outdoor air temperature in a highly ventilated free running house) one can calculate the appropriate total resistance for the roof construction.

In winterless climate locations such as north Queensland, it is important to utilize reflective air space insulation in roofs. This takes advantage of the lower resistance to heat flow up of a 100 mm reflective air space during nighttime, around 0.48 m^2K/W, to heat flow down during daylight hours, around 1.42 m^2K/W. This characteristic speeds house cooling after sundown (Aynsley & Su., 2005). Other types of roof insulation trap heat stored in walls and floors during the day indoors, slowing radiant cooling from the roof at night. Metal roof temperatures at night in Townsville, north Queensland, cooled by radiation to the sky have been measured at up to 8K below air temperature.

With respect to a rating scheme for free running houses, ISO 13791 (2004), *Thermal performance of buildings: Calculation of internal temperatures of a room in summer without mechanical cooling – General criteria and validation procedures*, could provide a suitable framework for assessing summer performance. Data tables in this standard would need to be replaced to reflect Australian conditions. Radiant heat transfer sections would need to be expanded to accommodate reflective air spaces that are not widely used in Europe.

The procedure for estimating natural ventilation in this standard follows the traditional wind-surface-pressure-difference/orifice-flow approach similar to that used in AccuRate. This method can result in underestimation of ventilation by up to 50% in well designed houses due to the inability to accommodate the influence of the following:

- dynamic pressure contribution to airflow on the windward side of openings,
- building porosity, and
- appropriate discharge coefficients for windows with casement sashes or doorways with hinged doors (Sawachi, 2006).

Current techniques for estimating the cooling effect of air speed on house occupants such as Equation 2 in the paper tend to significantly underestimate cooling effects as they cannot accommodate the influence of the following:

- gust frequency,
- reduced clothing insulation values, and
- mean radiant temperatures that exceed air temperature.

Before embracing ISO standards, it is wise to review tabulated design data. The ISO 13791 (2004) standard, for example, provides design data for 40° and 52° latitude. Where does 40° latitude fall with respect to Australia? Try the middle of Bass Strait! In other words, European free-running data is irrelevant to mainland Australia. Clearly Australia and other countries need standards like ISO 13791, but substantial work is needed to assemble the climatic design data needed.

References

Aynsley, R. (1997). Energy efficient design. Unpublished Master of Tropical Architecture distance learning course notes, James Cook University, Townsville - Week 5, Comparative Energy Use in Air Conditioned Forced Ventilated and Naturally Ventilated Houses.

Aynsley, R., & Su, B. (2005). Insulation of roofs in warm climates. In *Proceedings of the CIB/W107 International Symposium on Procurement Systems, Las Vegas*. Rotterdam: CIB. Pp. 617-625.

ISO 7730 (2005*). Ergonomics of thermal environment: Analytical determination and interpretation of thermal comfort using calculation of PMV and PPD indices and local comfort criteria*. Geneva: International Standards Organisation.

ISO 13791 (2004). *Thermal performance of buildings: Calculation of internal temperatures of a room in summer without mechanical cooling – General criteria and validation procedures*. Geneva: International Standards Organisation.

Koenigsberger, O.H., & Lynn, R (1965). *Roofs in the Warm Humid Tropics*. London: Lund Humphries.

Miller, A., & Ambrose, M. (2005). *Sustainable subdivisions: Energy-efficient design: Report to industry.* Brisbane, Australia: CRC for Construction Innovation.

Sawachi, T. (Gen Sec) (2006). 2nd Workshop on Natural Ventilation, Tokyo, December, 2005. *International Journal of Ventilation, 5*(1), 1-188.

University of Melbourne, Department of Architecture and Building (1981). Thermal performance of housing units in Queensland: A study for the Australian Housing Research Council *AHRC Report 58*. Melbourne: Author.

Comments from the Authors

The authors are very pleased to note Dr Aynsley's comments. The definition of 'free-running' performance used in the paper explicitly excludes the use of fans. While supported in the literature to avoid the complex issues of 'predicted energy use' (as distinct from the 'heating and cooling space loads' calculated by the software tool), we acknowledge that this definition becomes overly restrictive when more generally applied. Thus, Aynsley is correct to highlight that where fans are used for fine control of ventilation in warm climates, the building could still be safely characterised as 'free running' in contrast to 'artificially cooled'. If we need any excuse for excluding fans from our analysis, it is only that the reported study was explicitly confined to temperate climate zones.

We also agree that if a sensitivity analysis similar to that reported in the paper were to be employed to extend the proposed rating framework to warmer climates, it would be necessary to consider a treatment of radiant temperature beyond that incorporated in the simulation tool itself. The relatively simple method proposed by Aynsley is very appropriate, and highlights the critical importance of the correct level of ceiling insulation in free-running dwellings under overheated conditions.