AFIA

LOW EMISSION
HIGH REFLECTION

ALUMINIUM FOIL INSULATION ASSOCIATION INC.

- Member of IMAA–Insulation Manufacturers Assoc. Aust.

A0035961V

CONSULTANTS
- Robin Clarke–M.AIRAH (CSIRO–Building, Const, Eng.)
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ASSOCIATE MEMBERS
- Australian Aluminium Council
- Solatube/Enviromax (Ventilation)
- Sancell Aust. P/L

MEMBERS
- Aerodynamic Dev. P/L (EXPS Styrofoam+Foil)
- AFP Functional Coatings (Amcor Ltd)
- Astro-Foil(Aust.)P/L (Air-cell+Foil/continuous) – VICE PRESIDENT: B. Tikey
- 'Battmans' Insulating Services P/L (EPS+Foil)
- Consolidated Alloys (Foil)
- CSR Bradford (Thermofoil)
- Duroid P/L (Foil)
- Foil Board Aust. P/L (EPS+Foil) – TREASURER: L. Moylan
- Insulation Solutions (Sisalation)
- Kaal Aust. P/L (Micron Foil)
- Portco P/L (Foil)
- Renouf Inds. P/L (Renfoil)
- Rmax (EPS+Foil)
- Silver Batts P/L (Multi-cell Foil) – PRESIDENT: M. Bostrom
- Tasman Insulation P/L (Foil)
- Vespol P/L (Foil)
- Wren Inds P/L (Concertina Foil Batts) – SECRETARY: T. Renouf

5th July, 1999.

Mr. Phillip Harrington,
Executive Manager,
Sustainable Energy Group,
Australian Greenhouse Office,
GPO Box 621,
CANBERRA. ACT. 2601.

Dear Mr. Harrington,

<u>RE: AGO Funding for Radiation/Convection Testing</u>

Further to discussions with Leon Arundell of the AGO, AFIA would like to present the following case for your consideration. We understand that the AGO has about 20 funding proposals to currently consider and that one from AFIA would need to be submitted with some urgency during the next one to two months.

AFIA had its inaugural meeting in February this year and its membership comprises all foil insulation manufacturers in Australia and has technical support from such institutions as CSIRO-DBCE (Dept. Building, Construction and Engineering) Melbourne, AITA Townsville (Australian Institute of Tropical Architecture) and UNSW Sydney.

AFIA is one of four product Associations belonging to the national body called IMAA, the Insulation Manufacturers Association of Australia. The other Associations are:

FARIMA	Fibreglass and Rockwool Insulation Manufacturers Association.
ACIMA	Australian Cellulose Insulation Manufacturers Association.
PIMA	Polyester Insulation Manufacturers Association.

IMAA's Secretary, Kevin Herbert, is aware that AFIA has concerns about specific fundamental heat flow issues. In particular, the unresolved and contentious matter of determining the effects of radiant heat penetration on fibrous insulations.

Standards Committee BD/58/1 is soon to publish a 1999 AS/NZS Thermal Insulation Materials Performance Standard which covers all existing insulation products. The current Draft, requires:

> 4.2.2.1 test protocol. All test procedures described in the table and all computations shall be performed for appropriate environmental and installation conditions. All factors which may affect the thermal resistance of installed insulations shall be taken into account and shall be stated, including:
>
> - temperatures at all relevant points through the structure, including the hot and cold surfaces of the insulation material or assembly
> - air flow rate within or around the structure, including buoyancy or external-pressure driven air flows, ventilation through and convection within airspaces or porous insulation materials
> - radiant energy level, including the effects of radiation exchange to adjacent hot or cold surfaces and radiation penetration through porous insulation materials
> - dimensions and orientation of structures and materials
> - infrared reflectance of relevant surfaces

The thermal performance of aluminium reflective insulations are always expressed within the overall calculation of a Total R value of a building element (e.g. a wall or roof/ceiling). Reflective insulation does not have a designated "added" R value and depends on the existance of adjoining airspaces so as to resist radiation by high reflectivity (97%) and low emissivity (3%).

The thermal performance of all bulk and fibrous insulations are always expressed as "added" R values and are tested by a single overseas adopted method for **conducted** heat undertaken via the Guarded Hot Plate, whereby a hot plate is set at 33^0 and a cold plate at 13^0 (i.e. fixed boundary conditions) and the product inserted between. A linear relationship is typical - doubling the thickness equates to a doubling of R value. This wide temperature difference (20K) is appropriate for North American and European winter conditions where low outdoor winter temperatures are sustained for several months per year.

The Australian situation is entirely different, comprising much higher average winter temperatures and typically hot summers. Summer heat is **radiant** heat, not conducted. The underside of metal roofs in Queensland have been recorded by Prof. Aynsley AITA as often having radiating surface temperatures exceeding 100^0C. He is particularly concerned as Queensland, a populous state, is subjected to extended periods of high radiation (i.e. a dominant summer climate) requiring little or no winter heating (e.g. Tropics). High radiant heat levels are also experienced over virtually all of Australia and both CSIRO and AITA believe that there is strong potential for the effects of both radiation and convection to short-circuit the stated thermal performance, heat flow down, of installed low density fibrous insulation in particular. There is no shortage of evidence of community confusion every summer when consumers routinely ask why they are still hot when their ceilings <u>are</u> insulated (with fibrous material). The introduction of aluminium foil eliminates the radiation and the problem - a single downward facing foil surface constantly emits or re-radiates as little as 3% of all inward radiation.

There is also a tendency to focus only on the daytime summer heat gain in naturally ventilated houses in the warm humid coastal regions of Australia. In fact, the most critical issues are condensation in the roof space during the early morning hours and thermal comfort of occupants around 9pm when cooler thermal comfort criteria for sleeping is a critical factor. If bulk insulation is installed under the roofing or on top of the ceiling it severely retards heat loss from the interior of the building through the roof to the night sky. Reflective foil on the other hand has a low resistance to heat flow up, around one third of its resistance to heat flow down. This assists the building to cool rapidly after sundown. This attribute of reflective foil makes it a very energy efficient insulation material for use in warm humid coastal regions.

AS2627 (1993) currently recommends "added" R values across Australia for cooling, based on full house refrigerative airconditioning. This Standard has a mathematical impediment in its methodology which inhibits aluminium foil to be factored into a roof space and needs revision. For winterless climates such as Townsville and Mt. Isa, where prolonged high summer heat exists, "added" insulation of R3.5 and R4.0 respectively, is nominated. In tropical locations, the combination of fibrous insulation and refrigerative cooling can result in condensation occurring within the bulk insulation. This happens because the set comfort level for the appliance is virtually the same as the dew point temperature.

The more effective alternative is to provide reflective insulation in the roof/ceiling so that the ceiling underside temperature is reduced to an acceptable level. Unfortunately, what this actually represents in terms of Total R value is not readily available from existing Australian data. The elimination of radiation together with house ventilation and good shading will produce acceptable comfort levels, without the need for refrigerative cooling. Graphs by Prof. Aynsley are enclosed to highlight the benefit of incorporating foil, against heat flow down and the inappropriateness of increasing the level of bulk insulation.

AFIA understands that an AGO driven National Energy Code will be drafted in about 12 months with the intention of being inserted into the Building Code of Australia, paralleling with State co-operation. This Code will call up the AS/NZS Thermal Performance Standard to which all insulation materials must conform. The contentious issue regarding radiation for all insulations will then come into very clear focus.

The most immediate problem is with NatHERS and BERS energy rating programs which designate an averaged R value for reflective foil in roof spaces, when summer R values (heat flow down) are approximately three times greater than winter values (heat flow up). Where a house is demonstrably energy efficient and receives an unjustifiably low energy star rating, there is high potential for litigation. Refer Prof. Aynsley correspondence enclosed.

AFIA understands that a Tropical NatHERS meeting is scheduled for early August in Brisbane to resolve the issue of formulating a "comfort-based open envelope" version of NatHERS. For very different conditions ASHRAE (USA) summer heat flow down data exists for roof spaces (both reflective and ventilated) but its possible relevance to Australian building practice is questionable. Accordingly, AFIA believes, further local Australian-based investigative work needs to be undertaken and then factored into NatHERS in order that the best information produces a dependable house energy rating scheme.

AFIA contends that there is a debate over performance of insulation materials in respect to radiation and convection which undermines the clarity of messages and community acceptance of energy saving practices. AFIA believes the Federal Government should be supporting the process of clarifying these issues so that the goals of AGO to reduce overall national energy consumption (and greenhouse gas emissions) be achieved.

The effects of radiation and convection on bulk insulation are presently unknown and require resolution. AFIA does not have the means to do this and is appealing to the AGO to assist in funding several projects. These are in ranking order of priority:

<u>Stage 1 - Laboratory Radiation/Convection Testing</u> **Cost: $25,000-$30,000**

CSIRO - DBCE Melbourne (Robin Clarke). *Proposal enclosed.
Modified Guarded Hot Plate - incorporating approximately 10 tests, both bulk and foil.

Stage 2 - Field Testing **Cost: $60,000**

AITA - Townsville (Prof. Aynsley)
Record by Heat Flow Meters, continuously for 2-3 months, the amount of heat gain through roof/ceilings and walls. Three houses in different locations, comparing bulk and foil insulation products. Comparison and validation against Stage 1.

Stage 3 - Development of a New Version of NatHERS (i) Queensland **Cost: $30,000**
(ii) All States **Cost: $100,000**

Incorporate findings of Stages 1 and 2 into NatHERS and develop a "comfort-based" version of NatHERS based on a ventilated "open" envelope principle as opposed to "closed" which automatically requires expensive airconditioning. Option (ii) accounts for the production of appropriate national climatic files.

Stage 4 - Validation of New Version of NatHERS **Cost: $12,000**

Through field measurements in the real world.

The Queensland Department of Mines and Energy (Martin Gellender) has also been approached and has indicated possible State Government support to Stage 2. Stage 3 is crucial, because without it, NatHERS as it currently stands is inapplicable for the substantial areas of northern Australia.

The Draft Thermal Performance Standard of Committee BD/58/1 has already anticipated work of this nature to clarify performance where uncertainties are known to exist. The effects of radiation and convection, in particular, have been discussed at Committee level and the phraseology described above (Section 4.2.2.1 of the current Draft) was considered as the best way to present these issues. AFIA also intends to refer these issues to Committee EN/3 "Energy Building Code".

AFIA is looking to the AGO for a leading role in our request for financial assistance so as to aim for the involvement of a broader steering committee for the overall project entailing AFIA, Standards Australia, AGO, Queensland Government, Australian Aluminium Council and SEDA.

Yours sincerely,

Tim Renouf

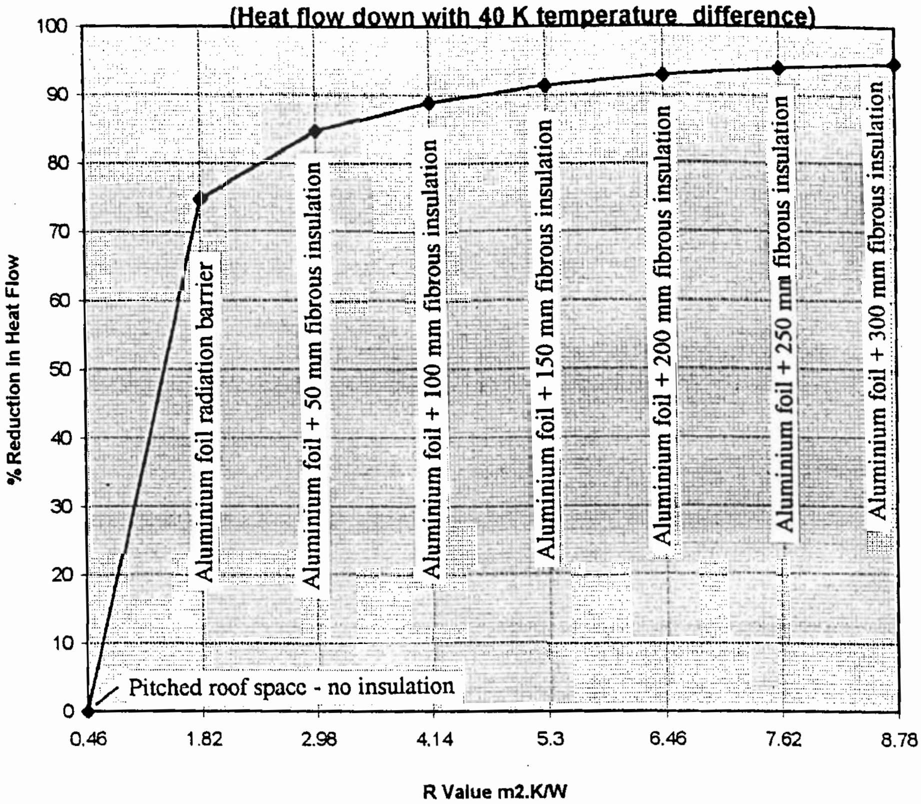
Tim Renouf,
Secretary - AFIA.

Enc.

(i)	Heat flow down graphs (6/99)	- Prof. R. Aynsley
(ii)	Correspondence to Angelo Delsante, CSIRO (21/11/98)	- Prof. R. Aynsley
(iii)	Correspondence to Tim Renouf, SEFIA (20/11/98)	- Prof. R. Aynsley
(iv)	Correspondence to Tim Renouf, AFIA (28/4/99)	- Prof. R. Aynsley
(v)	Longwave radiant heat transfer across building cavities (5/2/99)	- Prof. R. Aynsley
(vi)	Proposed Radiation Research Project, CSIRO-DBCE (7/9/98)	- R. Clarke

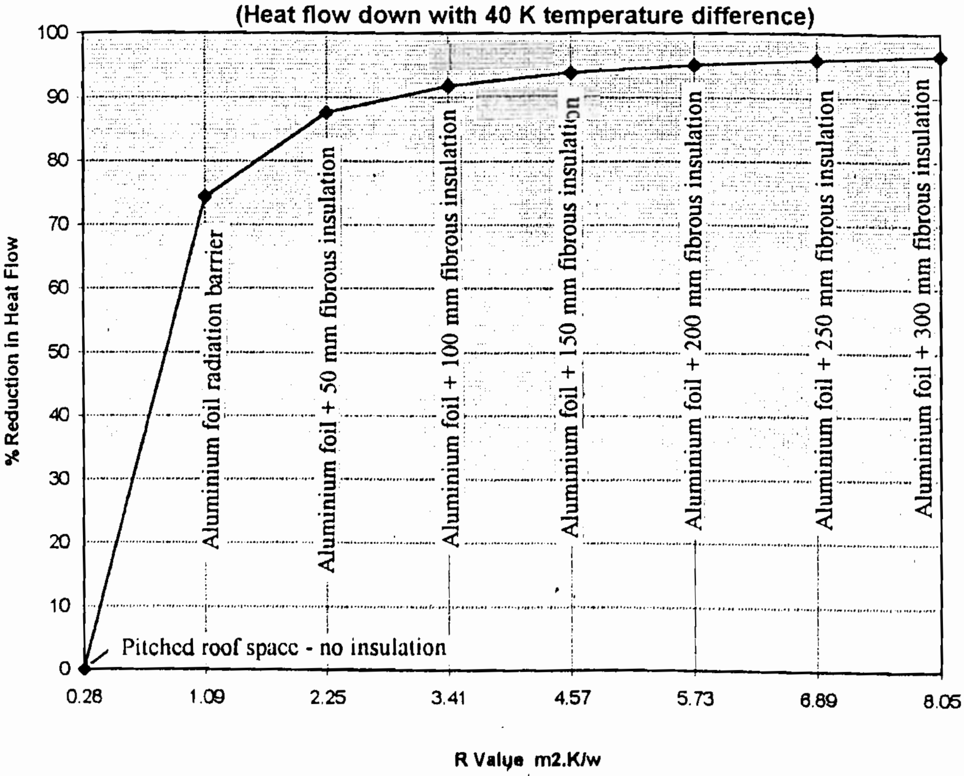
c.c.
- Standards Australia (Richard Bickle - Secretary BD/58/1 and EN/3)
- Queensland Govt. Dept. of Mines and Energy (Martin Gellender - Energy Innovation)
- SEDA (Belinda Kinkead - Project Leader Domestic Sector)
- Australian Aluminium Council (David Coutts - Executive Director)
- Insulation Manufacturers Assoc. Aust.-IMAA (Kevin Herbert - Secretary)

Percentage Reduction in Heat Flow
Through Ventilated Pitched Roof Space
Versus Increasing R Value of Insulation
(Heat flow down with 40 K temperature difference)



Computation by Australian Institute of Tropical Architecture, James Cook University, 1999, based on data from 1995 AIRAH Handbook

Percentage Reduction in Heat Flow
Through Non-Ventilated Pitched Roof Space
Versus Increasing R Value of Insulation
(Heat flow down with 40 K temperature difference)



Computation by Australian Institute of Tropical Architecture, James Cook University, 1999, based on data from 1995 AIRAH Handbook

(JUNE 1999)

The Australian Institute of Tropical Architecture

School of Public Health & Tropical Medicine

JAMES COOK UNIVERSITY

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FACSIMILE TRANSMISSION TO: Angelo Delsante - CSIRO

FAX: **03 9252 6240**

DATE: **21 November 1998**

SENDER: **Professor Richard (Dick) Aynsley, Director**

SUBJECT: **Copy FYI of Recent Fax to Tim Renouf**

Number of pages including this cover sheet: 1

Dear Angelo,

Attached is a copy of a fax sent to Tim Renouf for the SEFIA meeting to be held next Monday. It is important to develop the public interest argument in order to gain funding from SEDA. My suggestion is:

- to push the point that energy rating scheme software such as NatHERS is about to be applied on a nationwide basis.
- that the R ratings for bulk insulation used in the software are based on a test method which does not take account of longwave radiant heat transfer.

It is therefore important that R ratings incorporating longwave radiant heat transfer through bulk insulation be established to ensure that energy ratings using all types of insulation are equitably based.

Regards,

Dick A.

The Australian Institute of Tropical Architecture

School of Public Health & Tropical Medicine

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FACSIMILE TRANSMISSION TO: Tim Renouf - SEFIA

FAX:	**03 9532 5854**
DATE:	**20 November 1998**
SENDER:	**Professor Richard (Dick) Aynsley, Director**
SUBJECT:	**Need for Unified Insulation R Ratings**

Number of pages including this cover sheet: 1

Dear Tim,

The approaching Greenhouse gas emission reductions required of the building industry by the Commonwealth Government to meet its Kyoto commitments, is likely to be a once in a lifetime opportunity for the building insulation industry to prove its worth.

Great strides were achieved by building insulation industry representatives at the recent Standards meeting in reaching agreement on a single unified standard for building insulation. There is still another step to take. That is to determine a unified R rating for all insulation materials indicating their thermal resistance to the combined effects of air temperature difference and longwave radiant heat flux for heat flow up, down and laterally.

Some current R rating tests for building insulation do not include longwave radiation effects. Robin Clarke (CSIRO) and Angelo Delsante have given considerable thought to this problem and are prepared to arrange for unified upgraded testing to incorporate longwave radiation effects and ensure that the CHENATH thermal simulation engine for NatHERS and BERS reflects the outcomes from the upgraded testing.

As it is in the public interest to ensure that NatHERS and BERS energy rating schemes reflect the upgraded R ratings of thermal insulation materials for buildings it may be possible to gain a grant from SEDA to determine these new R ratings.

Regards,

R Aynsley

Professor Dick Aynsley
Director, AITA

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Tim Renouf
Secretary, AFIA
2A Bricker Street
CHELTENHAM, VIC. 3192

28 April 1999

THE RUSH TOWARD NATIONAL HERS:
Implications for Reflective Radiant Barriers in Winterless Climates

RELATIVE HEAT STRESS IN THE WINTERLESS NORTH

If building designers need more evidence of the dramatic differences between Australia's temperate climate regions and the warm humid tropics, they need look no further than the Bureau of Meteorology's "Climate Australia" (1989) which includes an analysis of relative heat discomfort as measured by the "Relative Strain Index" based on more than 40 years of climate records. The principal factor is the combined effects of high humidity/ air temperature in the *winterless north*..

CITY	**DAYS PER YEAR RELATIVE STRAIN INDEX > 0.3**
Canberra	3
Adelaide	6
Melbourne	6
Sydney	3
Brisbane	7
Townsville	**48**
Darwin	**173**

(From Climate Australia, 1989)

TEETH

In 1993, a group of concerned building design professionals with industry and community groups pooled resources to develop and promote a Townsville Energy Efficient Tropical House (TEETH). The participants were:

- James Cook University
- Australian Institute of Tropical Architecture
- Macks and Robinson Pty Ltd Architects
- North Queensland Regional Electricity Board
- North Queensland Science Education Centre, and
- Townsville College of Technical and Further Education

The house design optimised solar orientation and exposure to summer prevailing breezes for natural cross ventilation. Similar existing houses in Townsville are known to be thermally comfortable during summer with ceiling fans supplementing air flow during those relatively few occasions when breezes subside. Extensive boundary layer wind tunnel studies were conducted of air flow through the living room, kitchen, and bedrooms as well as flow visualisation in a detailed model of this house.

During summer, NatHERS or BERS closed envelope modelling of a house in a warm humid tropical climate (no winter) with large openings for natural cross ventilation would be inappropriate. This is illustrated by the fact that both NatHERS and BERS ratings for the Townsville Energy Efficiency Tropical House (TEETH) project house are 0 stars out of the best score of 5 stars. This is despite the effective shading of walls, reflective radiant bariers in the roof and good cross ventilation. Houses of this type are comfortable without air conditioning during the summer in warm humid regions and require little or no winter heating. Ceiling fans provide airflow when breezes subside with an energy demand of only about 1.3% of that for air conditioning. **More houses of this type would make Queensland housing the most energy efficient housing in the country.**

NatHERS FOR THE WARM HUMID WINTERLESS NORTH

Commonwealth and energy industry support for the development of a house energy rating system based on an existing American program led to the Nationwide House Energy Rating Scheme (NatHERS) computer software. While the closed envelope model used in the software was satisfactory for houses in temperate climates with significant winter heating and some summer cooling, it is not suited to naturally ventilated houses in warm humid winterless climates. In these climates there is basically no winter heating requirement and no need for a closed building envelope. Instead there is a dominant summer cooling requirement with a dominant humidity control component.

A simplification in CHENATH (used in Nathers & BERS) related to reflective roof cavities. uses a single R value of 0.85 m^2.K/W (average for heat flow up and heat flow down in a ventilated reflective roof cavity) instead of 1.36 m^2.K/W for heat flow down which applies in **winterless** climates. Over a full year, in a climate with significant heating and cooling, the overall energy associated with heating and cooling are acceptable. **However this simplification will underestimate the benefits of reflective roof spaces in reducing downward heat flow through the roof during daytime by (100 x(1.36 - 0.85/1.36)) 37.5% in winterless climates.**

Another simplification is in the choice of external solar absorptance values which are restricted to 25%, 50% or 80%. These are probably acceptable in temperate climates with both summer cooling and winter warming. However these simplifications lead to significant errors in energy calculations in winterless climates. Inability to use a solar absorptances of 11% in lieu of 25% in NatHERS and BERS results in an overestimation of cooling load by 13.7% by NatHERS and BERS. A solar absorptance of 11% is readily achieved with readily available white, reflective, high emittance roof paints.

In the coastal regions of Queensland, Northern Territory and Western Australia and even Northern New South Wales the majority of houses rely on cross ventilation from onshore breezes for daytime indoor summer comfort. The significant cooling effect of airflow on occupants, approximately 3.7°C for each metre per second of airflow, is highly cost effective and energy efficient but cannot be accommodated by the current closed envelope model used in NatHERS or its Queensland version Building Energy Rating Scheme (BERS).

CONSEQUENCES OF THE USE OF NatHERS & BERS IN THE WINTERLESS NORTH

If NatHERS or BERS software is used to energy rate effectively ventilated houses using reflective roof spaces in winterless climates, studies have shown that it will underrate the house by up to 4 stars. If this house is air conditioned it will consume about 100 times the energy used by ceiling fans to supplement natural cross ventilation by the prevailing breeze.

Energy rating of naturally cross ventilated houses using NatHERS or BERS software, is likely to encourage people to increase insulation and install air conditioning. This is likely to result in a 100 fold increase in energy consumption, frustrating the whole purpose of house energy rating. **Owners of expensive, well designed, naturally ventilated houses (some costing millions of dollars in North Queensland) are likely to be outraged when their houses are given a 0 Star energy rating when they know their houses are highly energy efficient**.

Federal, State or Local Government agencies involved in mandatory energy rating of houses would be well advised to have NatHERS and BERS star ratings validated with field studies of naturally ventilated houses in winterless climates before such programs are endorsed. Otherwise it will only be a matter of time before the massive class action legal suits come from property owners of highly energy efficient naturally ventilated houses in winterless climates whose houses have been unjustly devalued by low star energy ratings.

Yours faithfully,

Professor Richard Aynsley
UNESCO Chair in Tropical Architecture
B.Arch(Hons I), M.S.(ArchEng), Ph.D. (Building)
FRAIA, MAIRAH, MASHRAE, AASCE, MISB

AFIA

Aluminium Foil Insulation Association

Food for Thought

Professor Richard Aynsley
UNESCO Professor of Tropical Architecture
James Cook University

LONGWAVE RADIANT HEAT TRANSFER ACROSS BUILDING CAVITIES

Longwave (infrared) radiation is an important contributor to heat transfer across cavities in roof and wall construction. For simplicity in building design, resistance to such heat transfer is usually lumped in with resistance to heat transfer by conduction and convection into a single R value (m^2.K/W) for the cavity. It is important to note that heat transfer by conduction and convection is proportional to the temperature difference in degrees Kelvin across the cavity but heat transfer by radiation is proportional to the difference of the surface temperatures in degrees Kelvin raised to the fourth power. This simplification of lumping radiation with conduction and convection can result in significant error, particularly in countries like Australia where lightweight metal roofing and high intensities of solar radiation often result in metal roof temperatures over 100°C.

Consider heat transfer across a horizontal cavity in a low pitch metal decked roof. On a comfortable overcast day the zinc/aluminium finish metal roof temperature is likely to be approximately 60°C (333K) and the ceiling temperature is around 25°C (298K), a temperature difference of 35°C (35K). The AIRAH Handbook suggests an R value of 0.17 m^2.K/W for a 100 mm horizontal cavity with high emittance surfaces when heat flow is downward. For a temperature difference of 35K the heat transfer per square metre would be 206 Watts (35/0.17). Now consider downward heat transfer across the same horizontal roof cavity on a hot day when the metal roof is around 90°C (363K) and the ceiling temperature is around 55°C (328K), a temperature difference of 35°C (35K). The R value of 0.17 m^2.K/W and temperature difference of 35K remain the same the heat transfer per square metre would be the same 206 Watts (35/0.17).

The equation for the net radiant heat transfer across a cavity between two large parallel plates can be derived (Geankoplis, 1983) using Plank's law, Kirchhoff's law and the Stefan-Boltzmann law as:

$$Q = A (\sigma (T_1^4 - T_2^4)/(1/\varepsilon_1 + 1/\varepsilon_2 - 1)) \qquad W \qquad \text{(Equation 1)}$$

where:
- Q = net radiant heat exchange in Watts
- A = sample surface area of each of the large parallel plates taken as $1m^2$
- σ = Grashof number taken as 5.676×10^{-8}
- T_1 = Surface temperature of plate 1 in degrees Kelvin
- T_2 = Surface temperature of plate 2 in degrees Kelvin
- ε_1 = Longwave emissivity of surface of plate 1
- ε_2 = Longwave emissivity of surface of plate 2

Using this equation and assuming both surfaces have an emissivity of 0.9, the net radiant heat transfer across the cavity in the first example with surface temperatures of 298 K and 333 K is 205 Watts per square metre. The net radiant heat transfer across the cavity in the second example with surface temperatures of 328 K and 363 K is 269 W per square metre for the second example. This is a 31% increase in net radiant heat transfer across the cavity even though the temperature difference is the same.

Reflective Cavities

Now consider downward heat transfer across a *singly* reflective horizontal roof cavity (ε_1 = 0.2, ε_2 = 0.9) on a hot day when the metal roof is around 90°C (363K) and the ceiling temperature is around 55°C (328K), a temperature difference of 35°C (35K). The net radiant downward heat transfer from equation1 is 64 W/m^2 (49 W/m^2 if the temperatures are 60°C (333K) and 25°C (298K)).

Now consider downward heat transfer across a *doubly* reflective horizontal roof cavity (ε_1 = 0.2, ε_2 = 0.2) on a hot day when the metal roof is around 90°C (363K) and the ceiling temperature is around 55°C (328K), a temperature difference of 35°C (35K). The net radiant downward heat transfer from equation1 is 37 W/m^2 (28 W/m^2 if the temperatures are 60°C (333K) and 25°C (298K)).

Reference : Geankoplis, C. (1983) *Transport Processes: Momentum, Heat and Mass,* Allyn & Bacon Inc., Boston, page 276.

Professor Richard Aynsley, Director, Australian Institute of Tropical Architecture,
5 February 1999

INSULATION, CONDENSATION & METAL DECK ROOFS

The Bureau of Meteorology's publication Climatic Averages provides 14 percentile values for minimum daily temperature for each month for numerous recording sites around Australia. Statistically, air temperatures lower than these values can be expected to occur at least once per week. The same publication provides mean dew point temperatures at 9 AM and 3 PM for each month. There is usually little difference between morning and afternoon dew point temperatures as these reflect the absolute moisture content of the air which is linked to large pressure system movements in the atmosphere which typically take a number of days.

During most months, air temperatures will fall below the dew point temperature and dew will form on the upper and lower surfaces of metal roof decks. Dew on the upper surface of the metal decks will drain away via the normal roof drainage system. Where ambient air has access to the underside of the metal roof deck, dew forms on the underside of metal decks moves down the roof slope until it encounters a batten or purlin where it accumulates. This strongly suggests that access of ambient air to the underside of metal roof decking should be denied. This is commonly done by fixing bulk insulation with a foil vapour barrier on its facing down, hard against the underside of the metal roof deck and filling the ends of deep deck ribs with foam rubber inserts. The metal roof deck then acts as a vapour barriers at the upper surface of the bulk insulation. Without protection from condensation from metal roof decks, bulk insulation in roof spaces is likely to become damp and ineffective. There is widespread confusion regarding application of aluminium foil as a radiation barrier and as a vapour barrier which needs addressing by the industry.

Temperatures of metal roofs under skies with little cloud and air movement are likely to fall to between 4 and 8K below ambient air temperature due to nocturnal radiant heat loss to the sky. This means that condensation will probably form on metal roofing surfaces exposed to the air throughout the year as minimum air temperatures do not exceed dewpoint temperatures by more than 2.5K. This conforms with observations by the AITA on the Douglas campus during 1998/1999. Procedures for calculating night sky temperatures for estimating nocturnal radiant cooling are described on page 30.19 of the 1995 ASHRAE Handbook of HVAC Applications (SI edition). Procedures for estimating stagnation temperature of metal deck roofing cooled by infrared radiation to the night sky are provided in *Passive and Low Energy Cooling of Buildings* by B. Givoni, Van Nostrand Reinhold, New York 1994.

Professor Richard Aynsley, Director, Australian Institute of Tropical Architecture, 20 January 1999

SYDNEY (Regional Office)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Temperature °C dew point 9AM	17	17	16	13	9	7	5	6	8	11	13	15
Temperature °C 14 Percentile daily min.	16.7	16.8	15.6	12.3	8.9	7.2	6.1	7.1	8.6	10.9	13	14.8

MELBOURNE (Regional Office)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Temperature °C dew point 9AM	11	12	11	9	7	6	5	6	6	8	9	10
Temperature °C 14 Percentile daily min.	11.8	12.2	10.3	8.1	5.6	3.6	3.2	4.2	5.2	7.0	8.3	10.4

TOWNSVILLE (Garbutt)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Temperature °C dew point 9AM	22	22	21	19	16	13	12	14	15	17	19	20
Temperature °C 14 Percentile daily min.	21.8	22.4	20.6	17.9	13.9	11.1	8.8	11.3	14.3	17.9	20.6	21.7