Thermal Insulation Design Manual For the Pacific

TASMAN
INSULATION NEW ZEALAND
A Division of FletcherBuilding

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IMPORTANT NOTE

The use of suitable insulation in the hot and humid environment of the Pacific Region is essential. In many cases inadequate or low quality insulation results in severe structural and/or cosmetic damage.

THE AIM OF THIS DOCUMENT

This document has been developed as a reference for architects, government bodies and distributors in the Pacific Region. It's aim is to ensure that the insulation materials used are suitable for our tropical climate.

The use of *low quality* products within the Pacific Region is also a concern; in many instances these cheaper alternatives are unsuitable and/or dangerous and they do not meet Australian and New Zealand Fire Standards.

THREE AREAS OF CONCERN

Data gathered by experts in the region has identified three important areas of concern that we need to address immediately:

1. ALWAYS USE DOUBLE SIDED RADIANT BARRIERS

No reputable manufacturer, architect or project manager would recommend the installation of single sided aluminium foil as a radiant barrier in buildings. Single sided products, commonly installed in the Pacific Region, can deteriorate dramatically within 1 to 2 years due to the humid tropical environment. This deterioration diminishes the products insulation benefits dramatically.

The *minimum* specification for aluminium foil radiant barriers installed in any structure should be:

"a fire retardant, double sided, reinforced aluminium radiant/vapour barrier."

2. ALWAYS USE FIRE RETARDANT INSULATION MATERIALS

The use of non fire retardant aluminium foil radiant barriers is common in the Pacific Region. These products are unable to meet Australian and New Zealand Fire Standards due to their high flammability index.

It is highly recommended to specify and use only fire retardant insulation materials. To ensure the credibility of a fire retardant product we recommend that you specify and use only products that comply with:

AS1530 Part 2: with a Flammability Index less than 5 (ask for a copy of the certificate)

3. ALWAYS USE GLASS WOOL TOGETHER WITH A SUITABLE VAPOUR BARRIER IN AIR-CONDITIONED BUILDINGS.

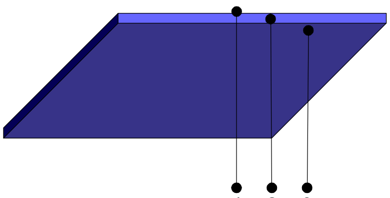
Any air-conditioned building requires glass wool insulation and the protection of a vapour barrier. Without the appropriate insulation and vapour barriers condensation damage often results.

Damages caused by condensation are obvious and well documented. Without a suitable vapour barrier humid moist air can pass through the glass wool insulation and can condense on the cooler surfaces within the structure, causing severe damage.

It is also commonly known that suitably insulated air-conditioned buildings use less electricity. These savings normally result in the investment in insulation paying for itself within 2-3 years. The savings in electricity continue every year for the life of the building.

Guidelines for Commercial Roof Structures in Tropical Environments

METAL ROOF - NO INSULATION - NO CEILING LINING — NO INSULATION



Description	R
1. Surface Film Outside (high)	0.04
2. Metal Roof	0.00
3. Surface Film Inside (high)	0.15
Total R-Value (metric)	**0.19**

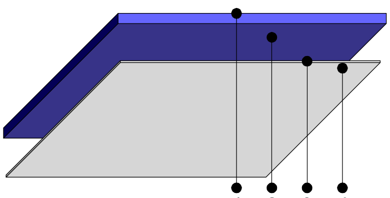
Structure: Basic. Metal sheeting is the only product used in this roofing structure. With no insulation radiant heat emitted from the metal roof increases the building's internal temperature dramatically.

Suitable: When temperature and comfort is not a consideration.

Total R-Value (Imperial) : 1.1 (0.19 x 5.678)

Comments: This structure does not comply with the minimum standard of insulation recommended by manufacturers.

METAL ROOF - NO CEILING LINING - FOIL OVER PURLINS — MINIMUM RECOMMENDED INSULATION



Description	R
1. Surface Film Outside (high)	0.04
2. 50mm Air Gap (high)	0.88
3. Duroid® Antiblaze® Heat Barrier	0.00
4. Surface Film Inside (low)	0.60
Total R-Value (metric)	**1.52**

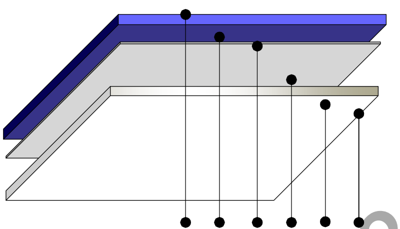
Method: One layer of Fire Retardant Foil Insulation installed over or under Purlins. Foil installed over the Purlins should sag to create a minimum 50mm insulating air gap.

Suitable: For a Non Air-conditioned Building

Total R-Value (Imperial) : 5.0 (0.88 x 5.678)

Comments: Suitable only for the most basic structures. Increasing the size of the air gap with increase its insulation value. Up to a maximum of R metric) = 1.08 with an air gap of 100mm or more.

METAL ROOF - FOIL OVER PURLINS - CEILING LINING — MINIMUM RECOMMENDED INSULATION



Description	R
1. Surface Film Outside (high)	0.04
2. 30mm Air Gap (low)	0.72
3. Duroid® Antiblaze® Heat Barrier	0.00
4. 100mm Air Gap (low)	1.08
5. Gib (12mm)	0.07
6. Surface Film Inside (high)	0.15
Total R-Value (metric)	**2.06**

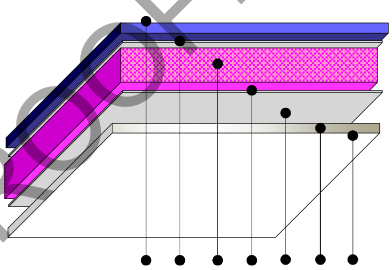
Method: One layer of Antiblaze® installed over the Purlins. Foil installed over the Purlins should sag to create an insulating air gap. By installing Gib® board onto the underside of the Purlins insulation is increased by creating another insulating air gap.

Suitable: Non Air-conditioned Building

Total R-Value (Imperial) : 11.7 (2.06 x 5.678)

Comments: Insulation has been greatly improved by the installation of a Gib® lining. This is an acceptable solution for non air-conditioned buildings where people and/or produce will be gathering. For air-conditioned buildings see the next example.

METAL ROOF - NO CEILING LINING - WITH AIR-CONDITIONING — MINIMUM RECOMMENDED INSULATION



Description	R
1. Surface Film Outside (high)	0.04
2. Duroid® Antiblaze® Vapour Barrier	0.00
3. R1.9 Glasswool Insulation	1.90
4. Duroid® Antiblaze® Heat Barrier	0.00
5. 50mm Air Gap (low)	0.88
6. Gib (12mm)	0.07
7. Surface Film Inside	0.15
Total R-Value (metric)	**3.04**

Method: Air conditioned buildings require the installation of glasswool together with a suitable vapour barrier to avoid condensation. In this case, as a minimum 75mm of Glasswool faced with a fire retardant vapour barrier (facing the exterior) is installed over or between the Purlins.

Suitable: Air-conditioned Building

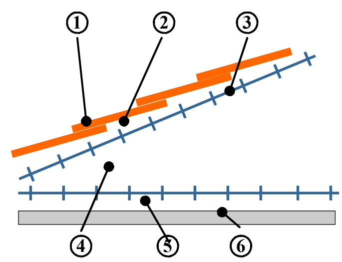
Total R-Value (Imperial) : 17.26 (3.04 x 5.678)

Comments: The glasswool has a greater resistance to the flow of heat than an air gap, protecting against the escape of cool air. Together with the low emissivity of a fire retardant heat barrier radiated heat is virtually eliminated.
Lower demand on air conditioning results in lower electricity bills so within 2-3 years the insulation has paid for itself.

NOTE: For the purposes of clarity Battens and Rafters have been omitted from the diagrams.

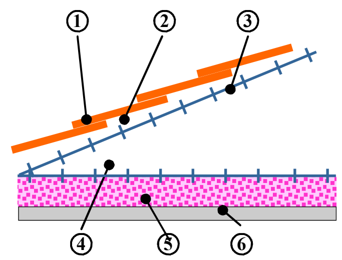
Guidelines for Residential Roof Structures in Tropical Environments

TILE ROOF - NO AIR CONDITIONING — MINIMUM RECOMMENDED INSULATION



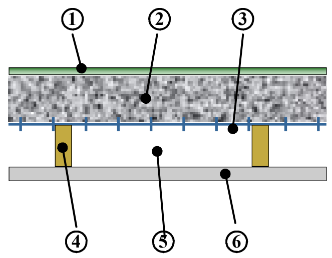
1.	Roofing Tiles	**Method:**	Fire Retardant Foil Insulation under Battens and over Ceiling Joists.
2.	Non Insulating Air Gap (Dusty)		
3.	Fire Retardant Foil Insulation	**Suitable:**	Non Air-conditioned Residential Structure
4.	Insulating Attic Space	**Rating:**	R-Value = 2.57
5.	Insulating Air Gap	**Comments:**	The presence of aluminium foil facing the air gaps and attic spaces faced turn them into excellent insulators against the suns heat.
6.	Ceiling Lining		

TILE ROOF - WITH AIR CONDITIONING — MINIMUM RECOMMENDED INSULATION



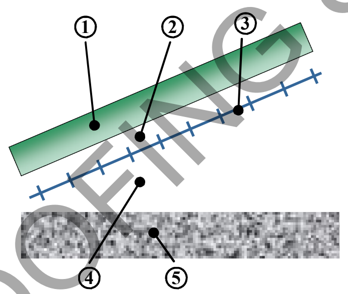
1.	Roofing Tiles	**Method:**	Fire Retardant Foil Insulation under Battens and Foil Faced 100mm Glass wool insulation with Aluminium Foil Vapour Barrier on Ceiling Lining.
2.	Non Insulating Airgap (Dusty)		
3.	Fire Retardant Foil Insulation	**Suitable:**	Air-conditioned Residential Structure
4.	Insulating Attic Space	**Rating:**	R-Value = 3.58
5.	100mm Foil Faced Glasswool	**Comments:**	While the foil insulation acts to reflect away the sun's heat, the glasswool and vapour barrier protects the cool interior from condensation.
6.	Ceiling Lining		

CONCRETE SLAB ROOF — MINIMUM RECOMMENDED INSULATION



1.	Roofing Sheet	**Method:**	Fire Retardant Foil Insulation held in place by 50mm rafters against which the ceiling lining is fixed creates an insulating air gap.
2.	Concrete		
3.	Fire Retardant Foil Insulation	**Suitable:**	Non Air-conditioned Building
4.	Purlins or Rafters	**Rating:**	R-Value = 1.38
5.	Insulating Air Gap (min. 50mm)	**Comments:**	To increase the insulation value of the roof structure the air gap can be increased or additional foil layers can be added.
6.	Ceiling Lining		

METAL ROOF WITH CONCRETE DECK — MINIMUM RECOMMENDED INSULATION



1.	Metal Roof	**Method:**	Fire Retardant Foil Insulation installed over purlins creating a low emissivity air gap and attic space.
2.	Insulating Air Gap (min. 50mm)		
3.	Fire Retardant Foil Insulation	**Suitable:**	Air-conditioned Building
4.	Insulating Attic Space	**Rating:**	R-Value = 2.08
5.	Concrete	**Comments:**	To further increase the insulation value of the structure a layer of fire retardant foil insulation can be installed together with a ceiling lining as above.

IMPORTANT GENERAL INSTALLATION GUIDELINES

- **Increasing an insulating air gap will increase the total thermal insulation value of the Fire Retardant Foil Insulation. Maximum R-Value is achieved with a 100mm air gap.**
- **It is essential that glasswool insulation is installed together with a vapour barrier in all air-conditioned buildings.**
- **For *every* situation we STRONGLY RECOMMEND a minimum specification of: "a fire retardant, double-sided, reinforced, aluminium foil radiant barrier"**

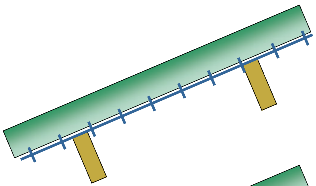
Installation Guidelines for Duroid® Antiblaze®

General Guidelines

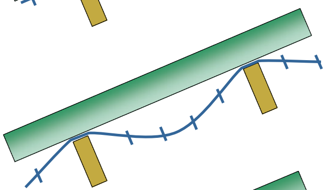
There are some fundamental rules to follow when installing Duroid® Antiblaze® fire retardant radiant heat and vapour barrier:

- Always ensure that the foil faces an air gap of at least 50mm either above or below the product.
- Overlap all edge joins by at least 75mm.
- When used as a vapour barrier seal all joins with aluminium self adhesive tape.
- Self Supporting products do not require supporting mesh if distance between supports is no more than 1.2m.

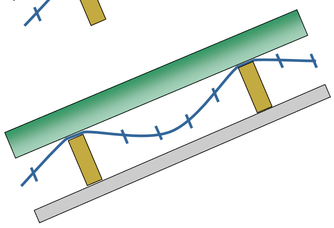
Over Purlins - Non Air-Conditioned Structures



Good: When installed over the purlins and pulled tight a small insulating air gap is formed above the layer of Duroid® Antiblaze® due to the corrugations in the sheet roofing. Some additional insulation is provided due to an open area below the product.

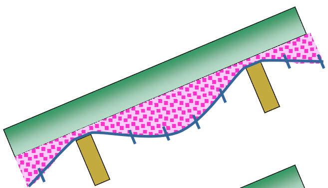


Better: When installed over the purlins and allowed to sag (up to 100mm) the insulating air gap and therefore the insulation value is increased. The open area below continues to offer a small amount of additional insulation. Installation MUST be sagged if roofing is not corrugated.

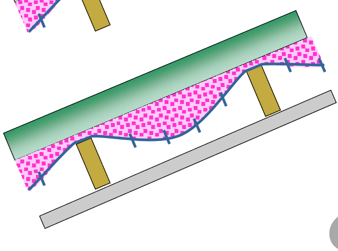


Best: The installation of Duralfoil® Antiblaze® has been sagged creating and insulating air gap with R-Value maximised. Installing Gypsum board as a ceiling panel creates another insulating air gap below the foil.

Acoustic Insulation - Non Air-Conditioned Structures

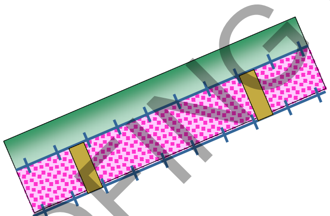


Good: A foil faced glasswool blanket can be used to deaden the noise of rain on a tin roof. When installing the blanket a supporting wire mesh can be used to lay the foil faced blanket out on. The wire mesh will hold the glass wool blanket securely against the tin roof. The aluminium foil on the underside of the blanket will offer increased insulation against the heat.



Better: Installing a ceiling of Gypsum board will increase both acoustic and thermal insulation values. By increasing the thickness or density of the glasswool acoustic and thermal properties will increase also.

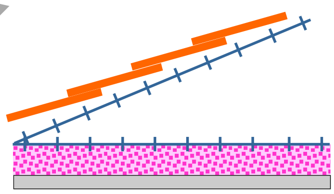
Air-Conditioned Structures - Thermal and Acoustic Insulation



Good: To avoid condensation forming on cold surfaces within the structure it is essential to install Duroid Antiblaze as a vapour barrier on the warmer side of a layer of 75mm thick glass wool insulation. When installing the glass wool it is essential that the blanket thickness not be compromised, this can be achieved by laying the glasswool *between* the purlins onto a supporting wire mesh.

Better: Installing a ceiling of Gypsum board will increase both acoustic and thermal insulation values. And/or adding a layer of Duroid® Antiblaze® under the glass wool blanket will increase thermal insulation. By increasing the thickness or density of the glasswool acoustic and thermal properties will increase also.

Residential Air-Conditioned Structures



Good: In residential structures with attic spaces the 75mm glass wool layer is best installed across the top of the false ceiling with the vapour barrier on top. A layer of Duroid® Antiblaze® can be installed along the inside of the purlins or rafters or over the purlins as above to provide protection against the entry of heat.

Better: The glass wool thickness can be increased for improved insulation and a greater savings in electricity through lower use of air-conditioning units.

PHYSICS OF FOIL

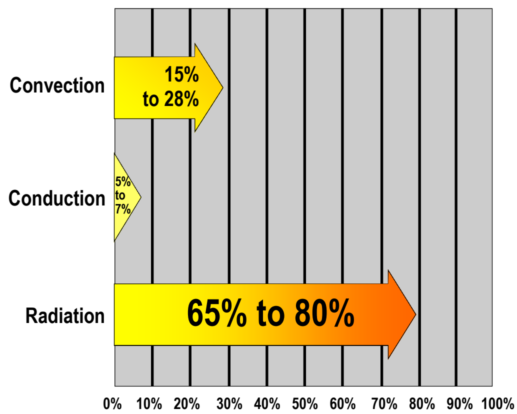
HEAT GAIN / LOSS IN BUILDINGS

There are three modes of heat transfer: CONDUCTION, CONVECTION, and RADIATION (Infra Red). Of the three, radiation is the primary mode; conduction and convection are secondary and come into play only as matter interrupts or interferes with radiant heat transfer. As the matter absorbs radiant energy, it is heated, develops a difference in temperature, and results in molecular motion (conduction in solids) or mass motion (convection with some conduction in liquids and gas).

All substances, including air spaces, building materials such as wood, glass and plaster, and insulation, obey the same laws of nature, and TRANSFER heat. Solid materials differ in the rate of heat transfer which is affected by differences in: density, shape, permeability and molecular structure. Materials which transfer heat slowly can be said to resist heat flow.

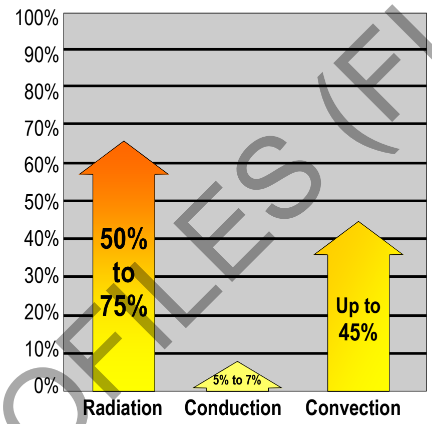
Direction of heat transfer is an important consideration. Heat is radiated and conducted in all directions, but convected primarily upward. The figures below show modes of heat loss and gain by houses. In all cases, radiation is the dominant mode.

SIDE HEAT FLOW



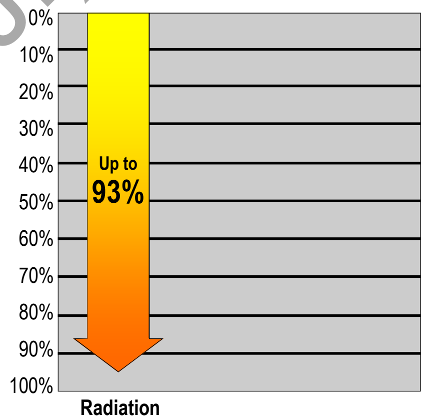
Heat Loss Through Walls

UP HEAT FLOW



Heat Loss Through Cieling/Roof

DOWN HEAT FLOW



Tropical Environments or Summer Heat Gain

CONDUCTION is direct heat flow through matter (molecular motion). It results from actual PHYSICAL CONTACT of one part of the same body with another part, or of one body with another. For instance, if one end of an iron rod is heated, the heat travels by conduction through the metal to the other end; the heat also travels to the surface and is conducted to the surrounding cooler air. An example of conduction through contact between two solids is a cooking pot on the solid surface of a hot stove. The greatest flow of heat possible between materials is where there is a direct conduction between solids. Heat is always conducted from warm to cold, never from cold to warm, and always moves via the shortest and easiest route.

In general, the more dense a substance, the better conductor it is. Solid rock, glass and aluminium-being very dense-are good conductors of heat. Reduce their density by mixing air into the mass, and their conductivity is reduced. Because air has low density, the percentage of heat transferred by conduction through air is comparatively small. For this reason air gaps, when utilised correctly, can potentially play a very important role in insulating a structure.

CONVECTION is the transport of heat within a gas or liquid, caused by the actual flow of the material itself (mass motion). In building spaces, natural convection heat flow is largely upward, somewhat sideways, but never downward. This is called "free convection."

For instance, a warm stove, person, floor, wall, etc., loses heat by conduction to the colder air in contact with it. This added heat activates (warms) the molecules of the air which expand, becoming less dense, and rise. Cooler, heavier air rushes in from the side and below to replace it. The popular expression "hot air rises" is exemplified by smoke rising from a chimney or a cigarette. The motion is turbulently upward, with a component of sideways motion. Convection may also be mechanically induced, as by a fan. This is called "forced convection."

RADIATION is the transmission of infrared rays through space. Radiation, like radio waves, is invisible and is commonly known as infrared rays. Each material that has a temperature above absolute zero (-273 C.) emits infrared radiation, including the sun, icebergs, stoves or radiators, humans, animals, furniture, ceilings, walls, floors, etc.

All objects radiate infrared rays from their surfaces in all directions, in a straight line, until they are reflected or absorbed by another object. Travelling at the speed of light, these rays are invisible, and they have NO TEMPERATURE, only ENERGY. Heating an object excites the surface molecules, causing them to give off infrared radiation. When these infrared rays strike the surface of another object, the rays are absorbed and only then is heat produced in the object. This heat spreads throughout the mass by conduction. The heated object then transmits infrared rays from exposed surfaces by radiation if these surfaces are exposed directly to an air space.

The amount of radiation emitted is a function of the EMISSIVITY factor of the source's surface. EMISSIVITY is the rate at which radiation (EMISSION) is given off. Absorption of radiation by an object is proportional to the asorbitivity factor of its surface which is reciprocal of its emissivity.

Although two objects may be identical, if the surface of one were covered with a material of 90% emissivity, and the surface of the other with a material of 5% emissivity, the result would be a drastic difference in the rate of radiation flow from these two objects. This is demonstrated by comparison of four identical, equally heated iron radiators covered with different materials. Paint one with aluminium paint and another with ordinary enamel. Cover the third with asbestos and the fourth with aluminium foil. Although all have the same temperature, the one covered with aluminium foil would radiate the least (lowest [5%] emissivity). The radiators covered with ordinary paint or asbestos would radiate most because they have the highest emissivity (even higher than the original iron). Painting over the aluminium paint or foil with ordinary paint changes the surface to 90% emissivity.

Materials whose surfaces do not appreciably reflect infrared rays, i.e.: paper, asphalt, wood, glass and rock, have absorption and emissivity rates ranging from 80% to 93%. Most materials used in building construction -- brick, stone, wood, paper, and so on -- regardless of their colour, absorb infrared radiation at about 90%. It is interesting to note that a mirror of glass is an excellent reflector of light but a very poor reflector of infrared radiation. Mirrors have about the same reflectivity for infrared as a heavy coating of black paint.

The surface of aluminium has the ability NOT TO ABSORB, but TO REFLECT 95% of the infrared rays which strike it. Since aluminium foil has such a low mass to air ratio, very little conduction can take place, particularly when only 5% of the rays are absorbed.

TRY THIS EXPERIMENT: Hold a sample of FOIL INSULATION close to your face, without touching. Soon you will feel the warmth of your own infrared rays bounding back from the SURFACE. The explanation: The emissivity of heat radiation of the surface of your face is 99%. The absorption of aluminium is only 5%. It sends back 95% of the rays. The absorption rate of your face is 99%. The net result is that you feel the warmth of your face reflected.

REFLECTIVITY AND AIR SPACES

In order to retard heat flow by conduction, walls and roofs are built with internal air spaces. Conduction and convection through these air spaces combined represent only 20% to 35% of the heat which pass through them. In both winter and summer, 65% to 80% of the heat that passes from a warm wall to a colder wall or through a ventilated attic does so by radiation.

The value of air spaces as thermal insulation must include the character of the enclosing surfaces. The surfaces greatly affect the amount of energy transferred by radiation, depending on the material's absorptivity and emissivity, and are the only way of modifying the total heat transferred across a given space. The importance of radiation cannot be overlooked in problems involving ordinary room temperatures.

The surfaces of ordinary building materials, including ordinary bulk insulation have a radiation or emissivity rate of about 90%, a heat ray absorption rate of over 90%. Surfaces lined with sheets of aluminium foil of 5% emissivity and absorptivity.

Reflection and emissivity by surfaces can ONLY occur in SPACE. The ideal space is any dimension 75mm or more. Smaller spaces are also effective, but decreasingly so. Where there is no air space, we have conduction through solids. When a reflective surface of a material is attached to a ceiling, floor or wall, that particular surface ceases to have radiant insulation value at the points in contact.

Heat control with aluminium foil is made possible by taking advantage of its low thermal emissivity and the low thermal conductivity of air. It is possible with layered foil and air to practically eliminate heat transfer by radiation and convection: a fact employed regularly by the NASA space program. In the space vehicle Columbia, ceramic tiles are imbedded with aluminium flakes which reflect heat before it can be absorbed. "Moon suits" are made of reflective foil surfaces surrounding trapped air for major temperature modification.

HEAT LOSS THROUGH AIR

There is no such thing as a "dead" air space as far as heat transfer is concerned, even in the case of a perfectly airtight compartment such as a thermos bottle. Convection currents are inevitable with differences in temperature between surfaces, if air or some other gas is present inside. Since air has some density, there will be some heat transfer by conduction if any surface of a so-called "dead" air space is heated. Finally, radiation, which accounts for 50% to 80% of all heat transfer, will pass through air (or a vacuum) with ease, just as radiation travels the many million miles that separate the earth from the sun.

Aluminium foil, with its reflective surface, can block the flow of radiation. Some foils have higher absorption and emissivity qualities than others. The variations run from 2% to 72%, a differential of over 2000%. Most aluminium insulation has only a 5% absorption and emissivity ratio. It is impervious to water vapour and convection currents, and reflects 95% of all radiant energy which strikes its air-bound surfaces.

HEAT LOSS THROUGH FLOORS

Heat is lost through floors primarily by radiation (up to 93%). When ALUMINUM insulation is installed in the ground floors and crawl spaces of cold buildings, it prevents the heat rays from penetrating down, reflecting the heat back into the building and warming the floor surfaces. Since aluminium is non-permeable, it is unaffected by ground vapours.

CONDENSATION

Water vapour is the gas phase of water. As a gas, it will expand or contract to fill any space it may be in. In a given space, with the air at a given temperature, there is a limited amount of vapour that can be suspended. Any excess will turn into water (or condensation). The point just before condensation commences is called 100% saturation (or 100% humidity). The condensation point is called dew point.

VAPOR LAWS

1. The higher the temperature, the more vapour the air can hold; the lower the temperature, the less vapour.
2. The larger the space, the more vapour it can hold; the smaller the space, the less vapour it can hold.
3. The more vapour in a given space, the greater will be its humidity level.
4. Vapour will flow from areas of greater humidity to those of lower humidity.
5. Permeability of insulation is a prerequisite for vapour transmission; the less permeable, the less vapour transfer.

Tropical areas generally experience high humidity levels, above 65%. If a room were vapour-proofed, and the temperature was gradually lowered, the humidity would rise until it reached 100%, although the amount of vapour would remain the same. If the temperature were further lowered, the excess amount of vapour for that temperature in that amount of space would fall out in the form of condensation. This principle is visibly demonstrated when we breathe in cold places. The warm air in our lungs and mouth can support the vapour quantity but is too much for the colder air, and so the excess vapour for that temperature condenses and the small particles of water become visible.

In conduction, heat flows to cold. The under surface of a roof, when cold in the winter, extracts heat out of the air with which it is in immediate contact. As a result, that air drops in temperature sufficiently to fall below the dew point (the temperature at which vapour condenses on a surface). The excess amount of vapour for that temperature falls out as condensation or frost which forms on to the underside of the roof.

Water vapour is able to penetrate plaster and wood readily. When the humid air comes in contact with materials within walls having a temperature below the dew point of the vapour, moisture or frost is formed within the walls. This moisture tends to accumulate over long periods of time without being noticed, which in time can cause building damage.

ALUMINIUM FOIL AS A VAPOUR BARRIER

To prevent condensation, a combination of glasswool insulation and an effective vapour barrier can be used to ensure that an impermeable surface is exposed to the humid air which is not of a low enough temperature to result in condensation. Vapour barriers are installed on the warmer, humid side of the glass wool insulation because mass insulation can allow vapour to flow through. Aluminium is impervious to water vapour and can therefore be used as a effective vapour barrier, and when installed with the correct thickness of glass wool will create a surface impervious to condensation.

Adapted from Physics of Foil, AVI ASTRO VALCOUR, Inc. publication.