Government of **Western Australia**
Department of **Finance**
Building Management and Works

Northern Regions Heating, Ventilation and Air Conditioning Design Guideline

A guide to the provision of air conditioning systems and the management of condensation in buildings in the northern regions of Western Australia.

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A.1	Important Notice & Disclaimer	Description of each Part deleted Reference to 2015 guide deleted
Part B	Principles of HVAC design and condensation management	Retitled from "General Information"
Part C	Specifiers' Guide	Retitled from "Achieving Best Practice

Enquiries

Please direct any enquiries regarding this document to:

Subject Matter Expert:

Senior Project Manager

North - Regional Programs

Building Management and Works

Document Controller:

Building Quality Officer

Building Research and Technical Services

Building Management and Works

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PART A. THIS GUIDE AND ITS PURPOSE

- Background information about the guide.
- How and where the guide should be applied.

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A.1 Important Notice and Disclaimer

The authors of this guide are committed to sharing knowledge relating to the challenges of delivering building projects in remote tropical environments.

The authors and the groups who developed this guide give no guarantee, nor make any claim whatsoever, that the information in the guide provides exhaustive coverage of the subject matter, nor is it guaranteed to be complete, accurate, up-to-date or reliable for any particular purpose.

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For any instance in Part C where a proprietary product is named, an alternative product as determined equal in quality, function etc, by BMW may be considered for substitution.

A.2 Acknowledgements

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- Alex Tiverios – Department of Finance Building Management and Works
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Authors – Technical Development

- Andrew Coopes – Department of Finance Building Management and Works
- Tim Franklin – Tim Franklin Engineering Pty Ltd
- Keith Whenmouth – Engawa Architects Pty Ltd
- Sue Thomas – Engawa Architects Pty Ltd

Contributors – Editorial

- Adele Peek – Department of Finance Building Management and Works
- Elizabeth Bazen – Department of Finance Building Management and Works
- James Taylor – Department of Finance Building Management and Works
- Gaylene Whenmouth – Write Click Communications

Contributors – Industry input (wishing to remain unnamed)

- Local Broome and Kimberley Contractors
- Perth OEM manufacturers and equipment suppliers
- Perth HVAC Consultants

A.3 Introduction – Tropical design

Air conditioning in the tropics creates a variety of issues. One of the most severe, and least understood risks, is condensation - what causes it and its consequences.

Some building projects take a low energy approach, using natural cooling first and air conditioning as a back-up option. To succeed, this approach requires both the building designer and the end user to be committed to the principles of low-energy design, and to understand and accept the consequences of this approach. This commitment does not exist in all projects, especially where the end user has little direct stake in the development of the building or its operation.

Design guides often present information about tropical design as a side commentary to a broader discussion about temperate climate design, and useful information that would benefit a wider audience is often lost in the technical detail of one discipline or another. As a result, important advice can be buried or under-developed and different parts of the same document may contain confusing or contradictory information.

This guide deals specifically with projects where mechanical air conditioning is the primary cooling method. It discusses how best to design for comfortable, efficient, cost effective, low maintenance climate control in the context of high seasonal temperatures and humidity. This approach manages the risk of huge operating and maintenance costs, premature equipment failure, corrosion, condensation, compromised insulation, mould growth, sick building syndrome and, in extreme cases, structural failure.

In developing this document, the authors referred to a number of publications, including the **Australian Building Codes Board 2011 - Condensation in Buildings Handbook** and **AIRAH Application Manual DA20 - Humid Tropical Air Conditioning**.

Many of the publications contain contradictory information about best practice tropical design because they handle the information as a side bar to the main subject, rather than as a main topic to be addressed.

This guide deals exclusively with design for tropical climates. It has integrated contributions from builders, property managers, architects and mechanical engineers involved in the delivery and management of buildings in the Kimberley and Pilbara regions of Western Australia - two of the remotest, harshest, hottest and most humid locations in Australia. The need for easily serviced, efficient and reliable air conditioning in such an environment is obvious, but the challenge it presents requires everyone involved to shift their thinking, be more collaborative, have a more considered approach to applying national codes and give greater attention to detail than may be usual practice in more temperate locations.

The examples of building failure cited in this guide may appear extreme, but the authors contend that the risk of system failure and condensation in air conditioned buildings in the tropics is very significant and the consequences often impossible to rectify. All examples in this guide have been drawn from the authors' direct experience, which collectively spans 60+ years of tropical design, construction and property management.

A.4 Development of the guide

In 2011, Building Management and Works (BMW), a division of the Western Australian Government's Department of Finance, developed a set of technical guidelines – *Air Conditioning Design Guideline for Humid Areas.*

The guidelines were commissioned to address the continued and increasing incidence of damage to buildings resulting from poorly-performing air conditioning systems and consequent condensation. They were specifically intended to inform technical decision making about the design and installation of mechanical services in the Kimberley and Pilbara regions of Western Australia.

In 2013, BMW recognised the need to engage a wider audience in a discussion about this subject and to develop a solution that integrated both architectural and engineering responses. The guide has been redeveloped in this edition, and it will be periodically updated to incorporate recent lessons and current thinking on best practice.

The redevelopment of this guide has been a project-based collaboration of BMW, Engawa Architects and Tim Franklin Engineering – consultants working on the development of a new state primary school at Broome North in the northwest corner of Western Australia.

Elements of the guide were field tested by the school's building contractor during construction in 2014. The document reflects the lessons coming out of the construction process.

This edition identifies the issues, their causes and current regional best practice for preventing this type of building failure. It includes information about building design and construction as well as specifications for design and installation of air conditioning systems.

The guide is relevant to all air conditioned building projects across the northern region of Western Australia. While it focuses on requirements for new construction, some sections - in particular the air conditioning specifications - may be useful to designers and facilities managers who want to improve the performance of existing buildings that are due for a major upgrade of mechanical services.

A.5 Purpose of the Guide

Some buildings are planned to take a low energy consumption route, using natural cooling first and air conditioning as a back-up. This can deliver comfortable, energy-efficient and individually controlled solutions with few of the risks associated with more heavily air conditioned buildings. However, to succeed, this approach requires both the designer and building occupier to be committed to low energy use. This commitment is unlikely to exist in all projects, especially those where the user/occupier has not been involved in the development of the project or the management of the final building.

This guide is relevant to all building projects in the northern coastal region that incorporate mechanical cooling in some form. It is particularly relevant for buildings that use mechanical cooling as their primary source of temperature control and those that operate at low set temperatures or are air-conditioned 24 hours a day.

The flowchart Figure 2 below will help the designer, building owner and builder decide which projects will benefit from this guide.

A.6 Geographic limits

This guide is relevant anywhere that the demand for mechanical cooling involves periods of high relative humidity at the same time as warmer temperatures. As a working document, however, BMW has defined the guide's area of application as the department's Northern Region (Pilbara and Kimberley), which approximately coincides with the state's hot humid summer climatic zone – i.e. the coastal margin from Onslow in the south west to Kununurra in the north east as identified in the Bureau of Meteorology map Figure 1 below.

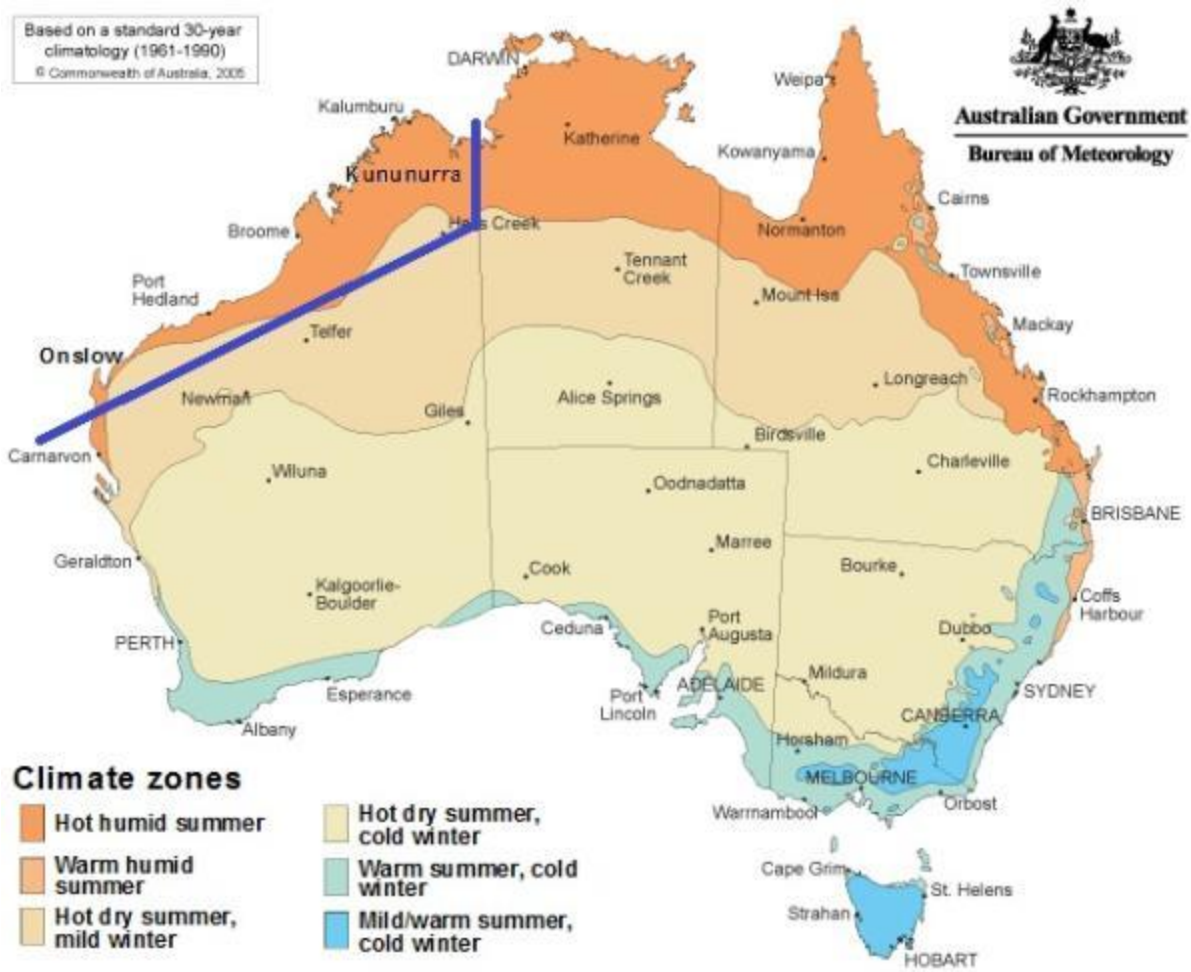


Figure 1 Australian climate zones based on temperature and humidity.

A.7 Decision Flow Chart

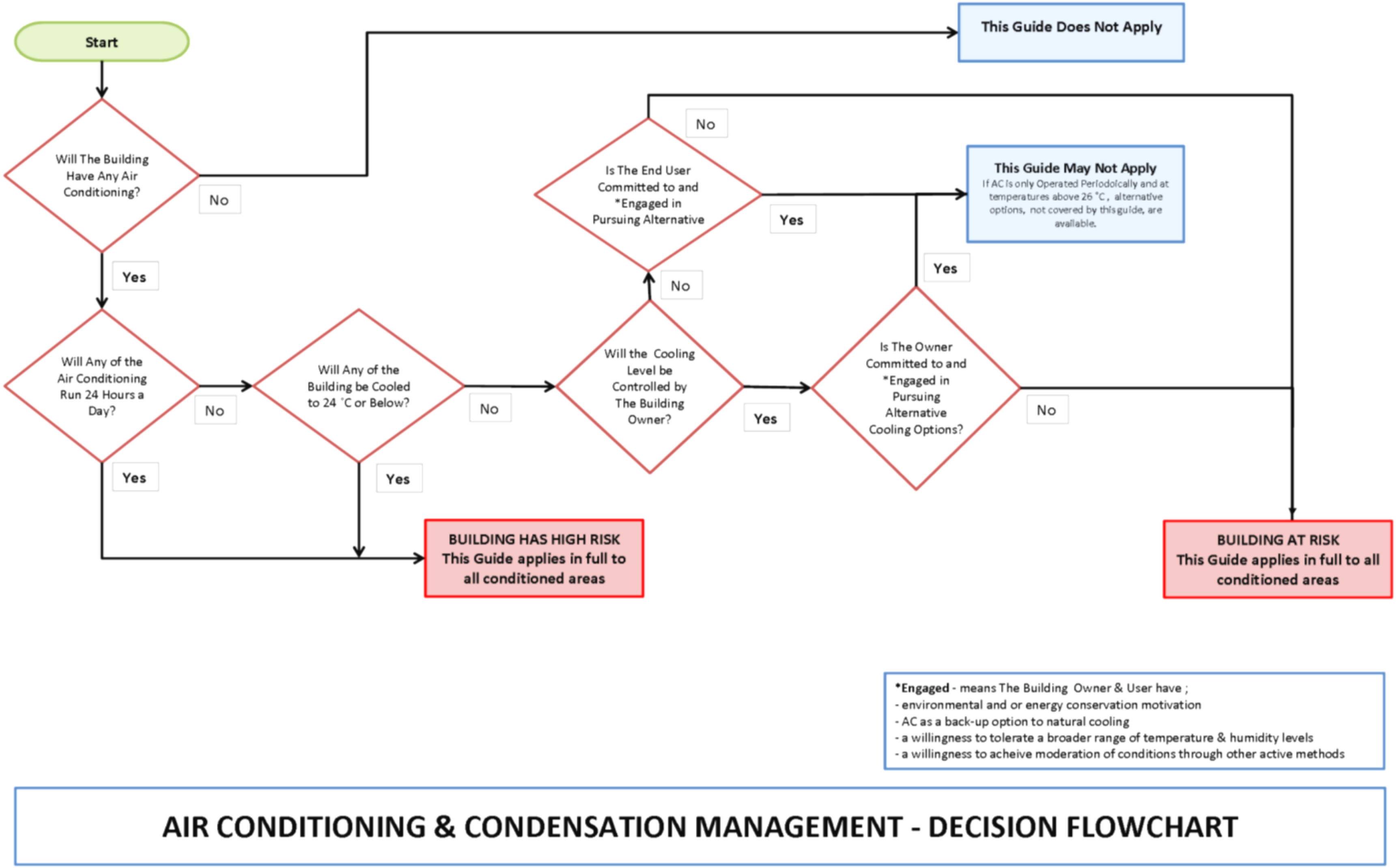


Figure 2

PART B. PRINCIPLES OF HVAC DESIGN AND CONDENSATION MANAGEMENT

- A general discussion of the principles relating to air conditioning in the tropics and managing condensation.
- Is suited to the lay person and is explanatory rather than mandatory or regulatory.

CONTENTS

B.1 Introduction

Part B is

- A general discussion of the principles relating to air conditioning and managing condensation.
- Is suited to include the lay person and is explanatory rather than mandatory nor regulatory.
- Neither mandatory nor regulatory and should be taken as providing general advice only.

Users should always obtain appropriate independent professional advice regarding the issues covered by this guide.

B.2 Design for Air Conditioning - Understanding the Risks in the Tropics

Poorly selected and installed air conditioning systems can cause the failure of buildings in the northern region of Western Australia. Similarly, buildings which have not been designed, detailed or constructed to deal with the condensation associated with the use of refrigerative cooling in the tropics are also at risk.

This is usually the result of:

- Poor understanding of regional conditions by designers, builders and operators who do not have experience in tropical regions.
- Ineffective management of the condensation risk by designers and installers.
- Poor system selection and specification by designers.
- Poor installation and maintenance practices by installers and building operators.

All are avoidable by:

- Making sound decisions at the design stage.
- Developing robust detailing and specifications in the documentation stage.
- Applying best practice standards of manufacture, installation and maintenance.

This section examines the scale and significance of the risks by reviewing some of the more frequent kinds of failure found in buildings across the region.

B.3 Regional Awareness

Many projects delivered in regional areas are designed by professionals from large, southern metropolitan centres who have little or no experience or understanding of the differences between their home environment and that of humid tropical regions. Some of these differences critically influence a building’s design, construction and operation.

Climatic heat is a primary design consideration for the Kimberley and Pilbara regions, but dealing with it is not simply a matter of applying more cooling. The heat brings with it a number of other less obvious, but just as important, factors that must be managed.

B.3.1 Extended periods of high humidity in addition to high temperature

The hot climate of the coastal margin of the Kimberly and Pilbara regions typically has an extended period of high humidity from early November to late March. During this time the

dew point of ***ambient air*** is frequently above the ***set temperature*** of most air conditioned spaces. This means that condensation will occur anywhere outdoor air contacts a surface that has been cooled by the air conditioning process. It also means that the performance of an air conditioning system needs to be measured as much by its ability to manage humidity as by its ability to manage temperature. This is especially the case when the ambient temperature is relatively low but the humidity remains very high.

B.3.2 Heat and humidity and its effect on corrosion of equipment

Heat and moisture accelerate corrosion – especially if dissimilar materials are in contact with each other. This situation is further exacerbated in coastal areas where the warm humid air also carries salt from the nearby ocean, creating a corrosive cocktail that can infiltrate into equipment and into the building fabric. Materials specification must take into account the heightened risk of corrosion in this environment; otherwise premature failure can be expected.

Figure 3 Example of corrosion frequently found in external units

B.3.3 Wildlife nesting in equipment

The region has an abundance of wildlife, much of which has no regard for human occupation. Creatures like termites, ants and rats will aggressively attack many types of building materials, including cable insulation, causing their disintegration and failure. Others - like frogs, geckos, birds and cockroaches - are likely to nest in building cavities and inside equipment enclosures. This introduces corrosive animal waste and nesting materials to places where they can damage the building or equipment itself. Such infestation will attract snakes which can damage equipment. It is therefore critically important to ensure diligent vermin proofing and to carefully position equipment out of harm's way.

B.3.4 Impacts of vegetation

In this region, building margins are often well planted in order to shade the building and create cool shaded outdoor areas. Outside condenser units are often mounted within these landscaped areas. This provides good screening but reduces efficiency because equipment becomes choked with plant material and corrosion occurs if wet plant material gets trapped inside the equipment housing.

Figure 4 Vegetation and wind-blown debris accumulate easily under and around external mechanical equipment

B.3.5 Exposure to Climate

The region experiences periodic cyclones and times of high very intense rainfall.

Cyclones present a risk to any externally mounted equipment, especially anything mounted in the open at roof level. The primary risk is to the mounting of the equipment itself, which must be sufficient to resist cyclonic wind forces. A secondary, but still significant, risk is that of wind-blown debris which could severely damage exposed equipment.

Very few areas in the region have a functioning in-ground stormwater system. This means that most developments will rely on overland flow for stormwater management. As a result, rising water and localised flooding can cause conditions to change very quickly with large volumes of water moving rapidly across areas that usually are completely dry. Care needs to be taken in the placement of all outdoor equipment to ensure it remains dry and out of seasonal stormwater flow paths.

B.4 Managing the Condensation Risk

B.4.1 Managing the condensation risk

Controlling the ingress of water into buildings is one of the key technical challenges for most designers, builders and facilities managers and the construction industry has time tested solutions for dealing with situations such as intense rainfall, stormwater runoff and rising damp.

This section deals with the challenges presented by condensation in a humid climate. This particular challenge is less well understood by designers and builders, and is often ignored until the problem reveals itself and it is too late to effectively rectify.

A minor leak in a building, when it rains, can often be tolerated with little impact on the building. The impact of condensation in a humid environment, however, can be more severe than any leak because there is rarely any relief. Once it starts, condensation will persist as long as the contributing conditions prevail. Unlike a leak, which has a chance to dry out once the rain stops condensation can continue for months at a time. This can be a big surprise to the unaware.

Warm tropical air can carry significant volumes of water as vapour. This vapour will readily condense onto any cool surface e.g. an air conditioning coil, an air supply grille, a cool floor or a chilled glass.

Figure 5 Condensation at its best – outside

Cooling a building below the ***ambient temperature*** significantly increases the risk of condensation occurring, not just on cooling equipment but on any part of the building that comes into contact with warm, humid outdoor air. A cool surface does not even have to be particularly cold. On an average February day in Broome, condensate will start to form on anything cooler than 27ºC.

Persistent condensation can lead to significantly increased operating and maintenance costs, health risks from slippery surfaces and mould growth and, in extreme cases, catastrophic failure of building materials and structure. Once condensation problems are established they are very difficult and expensive to rectify, particularly within concealed voids of buildings.

Figure 6 Mould on ceiling formed from condensation dripping from un-sarked roof above

Figure 7 Mould formed in wall sheeting saturated by condensation

B.4.2 How it happens - the science of condensation

Air contains invisible water vapour. Warm air can carry more water vapour than cold air. The higher the air temperature, the more water vapour it can carry. The lower the air temperature, the less water vapour it will hold.

When warm air contacts a cold surface, the air cools. When the air cools below a temperature known as the ***dew point***, the water vapour condenses to visible water droplets on the cold surface. The water that is formed is known as condensate and the process is called condensation. If further water vapour is present beyond the initial contact, condensation continues to occur and may lead to a trickle of condensate. However the process is reversible - if the surface is warmed above the dew point, the condensation will evaporate and may leave the surface dry.

Common examples of surface condensation include:

- On a cold glass of liquid as a result of the reduced temperature of the glass and its contents in the warm environment.
- On a bathroom mirror, as a result of increased moisture levels within the room.

In cooler climates, the people in a building are the largest source of water vapour which may lead to condensation. In warm humid climates the largest (almost limitless) source of water vapour is found in outdoor air. These two sources have to be managed differently when it comes to building design.

Water vapour from outdoor air will enter a building through:

- Outdoor air introduced through a ventilation system.
- Air leakage through poorly sealed doors, windows and other building elements.
- Migration through permeable materials due to the difference in vapour pressure between inside and outside.

Up to 95% of water vapour will enter a building through air leakage. Only 5% will migrate through building materials due to vapour pressure.

The cooling fins of a properly tuned air conditioner will generally remove excess moisture from outdoor air that is drawn, via a duct, into the building. Outdoor air which leaks into the building through an open door or gaps in the building fabric, will be cooled to below dew point by the building structure before it ever comes near an A/C unit. This air leakage is the most significant contributor to condensation problems.

At 33^{o}C and 70 per cent Relative Humidity (RH) - an average February day in Broome - the outdoor air holds 23.5gms of water per kg of air[1]. If this air enters a building and is cooled from 33^{o}C to 24^{o}C, it will deposit 5ml of water (per kg of air) as condensate on any cooled surface. In the tropics, it is possible for this rate of condensation to occur continuously for up to 6 months with the risk of catastrophic impacts on the building, especially within concealed cavities.

Condensation is a risk to any air conditioned building, but the risk increases dramatically where a building is:

- In a tropical humid environment – because of the higher humidity and high dew point
- Cooled for extended periods e.g. 24/7 - as is the case with hospitals, police stations and ambulance centres - where there is little opportunity for even minor condensation to dry out

[1] Dew point in these conditions is approximately 27.5^{o}C and 1 kg of air is approximately 0.8m^{3}

- Cooled to very low temperatures – as is the case with health care facilities, operating theatres etc – because these temperatures are significantly below the dew point, increasing the vapour pressure and the amount of excess water vapour to be removed from the air.

B.5 Why Condensation Appears to have Worsened

Condensation appears to be causing the failure of an increasing number of buildings. The problem has, in fact, existed for as long as refrigeration has been used for cooling and is well known and understood by specialists in the industry. There are, however, a number of factors that affect the way the problem is perceived:

- The conditions that lead to problematic condensation are seasonal and so the symptoms may only present themselves from time to time and may be more or less severe depending on the climatic conditions from one season to another. Evidence of a problem may therefore not be noticed until one or two seasons have passed.
- People now have higher expectations of thermal comfort, resulting in a steady increase in the use of air-conditioning as a means of climate control. This, coupled with the increased availability of affordable and more efficient air-conditioners, means the number of installations has increased and the potential for problems has multiplied accordingly.
- There is little regulatory control over air conditioning installation and use, particularly in domestic homes. Many installations are undertaken as a retrofit into an existing building or without full reference to the relevant design standards. Buildings may not have been designed or built to manage water vapour ingress and the resulting condensation.
- Recent initiatives to improve thermal performance of buildings have reduced energy consumption but have resulted in:
    - Buildings becoming significantly more airtight. The reduced ventilation of buildings, including interstitial areas, facilitates the accumulation of moisture and severely limits capacity for drying out. As a result, moisture retention and the impact of moisture can be more pronounced. This facilitates the development of mould, fungus and corrosion on surfaces and within cavities. This growth usually goes undetected until the problem becomes visible as fungus, mould or water staining on the walls, ceilings and other room surfaces.
    - A considerable increase in insulation levels. This helps keep internal spaces cooler for the occupants, but in air-conditioned environments it creates a risk of condensation occurring on internal surfaces.
    - Many modern air-conditioners are designed for energy efficiency and no longer have the capacity to significantly dehumidify the air before they reach the set temperature.
- There is a steady stream of southern designers, with little or no experience of building in the tropics, keen to learn on the job by attempting their first tropical regional project.
- Systems that are sized for high heat load conditions can be ineffectual at removing humidity at lower temperatures. This is because the over-sized cooling system reaches the set temperature quickly and shuts down before all the humidity has been removed

B.6 Where Condensation Happens

This section discusses the ways that condensation manifests itself, where it might occur and the likely underlying causes.

Condensation will occur anywhere warm moist air is cooled below dew point. Most often it will appear as water droplets on a cool surface. However with permeable surfaces like timber and plasterboard, the condensate is almost immediately absorbed and it may go un-noticed until the material's capacity to carry the moisture is exceeded.

What actually happens will vary from building to building but there are predictable locations where condensation will occur on surfaces given the right conditions.

B.6.1 Internal

Surface condensation can form as visible moisture on any cool internal surface. Mild situations may be limited to a film of moisture which is quickly reabsorbed into the air as internal conditions fluctuate. More serious conditions can result in continuous heavy condensation that, at best, presents a housekeeping issue - as wet surfaces need to be dried before the water causes any damage, and at worst presents a safety concern - with water running or dripping onto floors creating a slip hazard.

Condensation-susceptible sites include:

- Air conditioning equipment and ducts exposed to outdoor air
- Air conditioning registers and adjacent surfaces cooled directly by the flow of cold air which can be significantly colder than the room set point.
- Other surfaces cooled by air flow from air conditioning outlets
- Surfaces adjacent to external doors and windows that are exposed to air infiltration
- Wall and floor surfaces cooled through proximity to air conditioned spaces
- Note that condensation on permeable surfaces such as timber and plasterboard may be absorbed quickly and therefore go unnoticed. If the condensation continues it is likely that the first real evidence will be staining and/or mould growth on the affected surface.

B.6.2 External

Condensation will also occur on outside surfaces where the cool from inside is transferred to the building's outer skin. As with internal condensation, mild situations will typically resolve by themselves whereas more serious situations will result in unsightly and potentially dangerous wet patches, mould growth, corrosion or other building failure-promoting condition.

Condensation-susceptible sites include:

- Uninsulated glazing;
- Pressed metal door frames;
- metal window frames;
- Uninsulated building elements including structural steel and single skin block work;
- Uninsulated suspended floors – timber or concrete slabs;
- Uninsulated condensate drains;
- Uninsulated service penetrations; and

- Timber doors.

Visible surface condensation anywhere can also be a warning that there may be problems developing unseen within the building structure as interstitial condensation. This should be investigated rather than being left unchecked.

Figure 8 Condensation on outside face of door, frame and hardware due to cold tracking from cooled space

B.6.3 Interstitial condensation

This is condensation that forms on surfaces within a building element, such as inside a wall cavity. It occurs when the water vapour in outdoor air is able to infiltrate the building structure either through air movement or by diffusion through permeable building materials. Once this vapour reaches a cool surface within the cavity; condensate forms. The surface may be smooth such as sheet metal, or fibrous, such as glasswool insulation.

This type of condensation can be far more damaging to a building than surface condensation because it can go unnoticed for a long time. The longer it is left unchecked, the more likely it is to affect the building structure as well as cause cosmetic and mould-related problems.

Intermittent interstitial condensation will rarely lead to lasting problems, as condensate is reabsorbed into the air once conditions change. However, if there are extended periods of condensation, a considerable amount of water may become trapped within the building structure. If the building fabric allows moisture ingress, and it cannot dry out, mould growth and corrosion will occur and compromise the durability of the building and the health of the occupants.

Conditions that may lead to interstitial condensation include:

- Inadequacy of the insulation including:
  - No insulation;
  - Lack of continuity or gaps in the insulation;
  - Cold bridging due to structural elements penetrating the insulation; or
  - Cold bridging due to services penetrating the insulation.
- Inadequacy of the vapour barrier including:
  - No vapour barrier;

- Incorrect position of vapour barrier in the building element; or
- Lack of continuity - gaps or damage - in the vapour barrier.

B.7 What Happens When It Goes Wrong - Examples of Failure

This section discusses some of the more common problems associated with condensation. Even moderate levels of condensation in a building can create significant management problems for a building owner such as:

- Mould and fungus growth
- Water damage and corrosion
- Failure of insulation
- Phantom leaks
- Surface condensation
- Electrical safety hazard.

Figure 9 Evidence of interstitial condensation in wall

B.7.1 Mould and fungus growth

Mould in a building can create unhealthy living and working conditions and is one of the key contributors to sick building syndrome. It can also lead to the progressive deterioration of building finishes and structure, e.g.

- Severe mould growth in wall and ceiling linings and rot in timber framing
- Surface mould growth on outside face of external doors, door frames and external wall cladding.

Mould spores are ever-present in the environment. Most common strains flourish at temperatures between 21^{o}C and 30^{o}C and a relative humidity between 60 and 90 per cent. It is important is to ensure that conditions do not allow them to multiply and flourish.

The psychrometric chart below (Figure 10) shows the temperature and humidity range that supports mould growth and the range of conditions that satisfy human comfort expectations. Climate control should attempt to keep conditions outside the **mould alert zone.**

In warm humid climates, ambient humidity is constantly at levels that support mould growth for 5-6 months or more every year. A room left closed and unventilated in these conditions will go mouldy. Using ceiling fans to create air movement can help change conditions and retard some mould growth. The same venting principle applied to wall and ceiling cavities would also reduce the risk of rot.

Even air conditioned spaces, with the temperature set to 24^{o}C, are in the mould-promoting zone unless relative humidity is reduced to below 60 per cent. When humidity is high and external temperatures relatively low (say 27^{o}C to 28^{o}C), most conventional air conditioning systems will not remove enough moisture from the air before they reach the set temperature and shut down. If high levels of humidity persist and/or condensation is occurring, mould will also be flourishing.

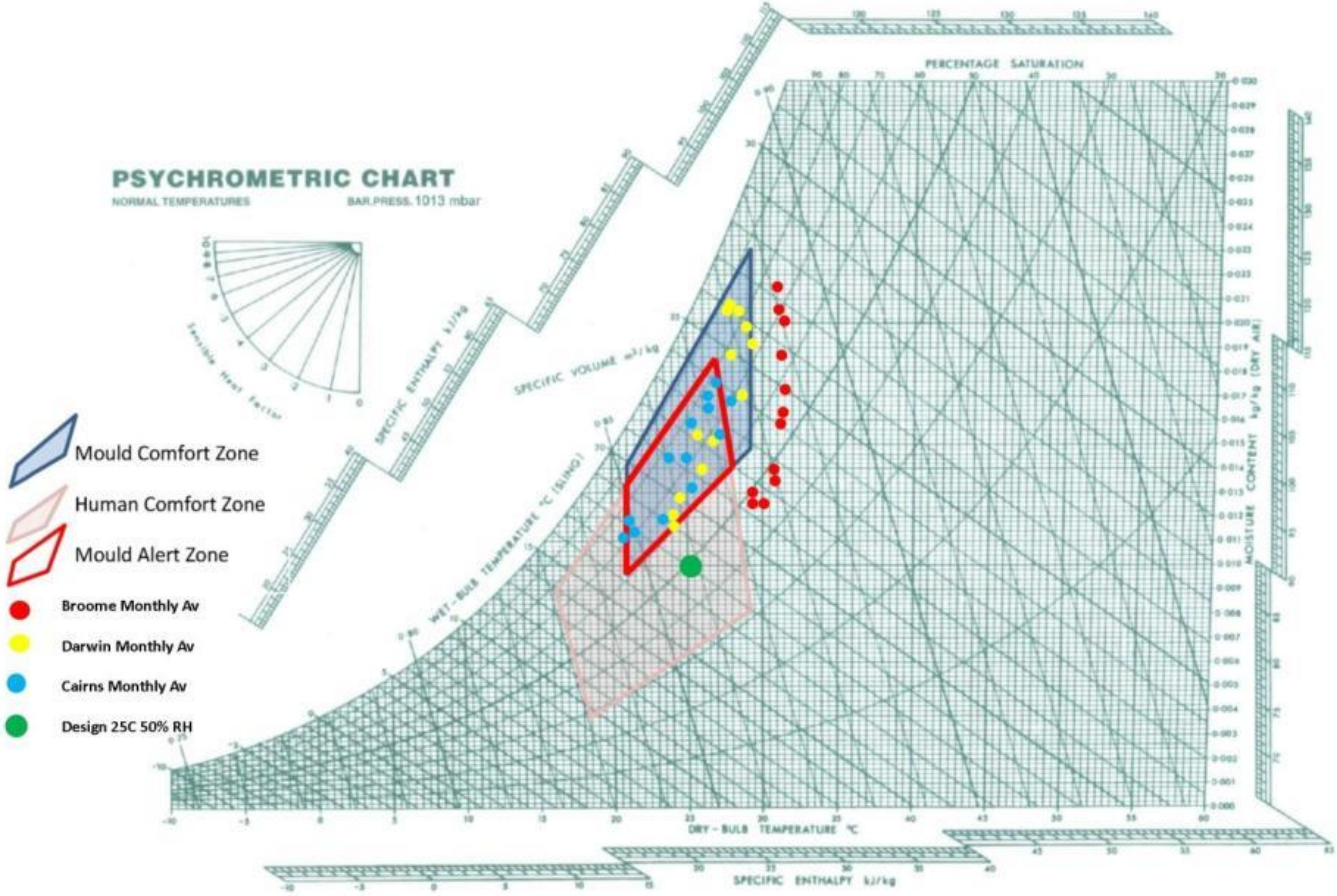


Figure 10 Psychometric chart showing the "mould alert zone"

B.7.2 Water Damage and Corrosion

B.7.2.1 Moisture Retention

Hygroscopic (absorbent) materials such as timber and plasterboard have a capacity to absorb, retain and release moisture depending on the surrounding environment. Condensation will very rarely be seen dripping from timber because of its capacity to absorb moisture. However, if the moisture content of timber exceeds 18-20% (by mass) for prolonged periods it can become susceptible to rot and fungal attack and affect the structural integrity of the building. An example of this is where condensation forms on the face of sarking and runs down the face of the sarking to collect at noggins or at the bottom plate where it is unable to dry out before damage becomes critical or irreversible such as:

- Collapse of saturated plasterboard ceilings and walls
- Extensive rot in timber framing and corrosion of steel.

Even if moisture levels never reach the levels required to support mould growth or decay, when condensation builds up over time, it can corrode adjacent fasteners, metal framing, sheeting, foil sarking or any metal components that have not been designed to tolerate such levels of moisture.

Figure 11 Corrosion in framing due to moisture retention in wall panel

B.7.2.2 Salt Corrosion

Building materials frequently contain salts and chemical preservatives which remain relatively inert when dry. In a high humidity environment or when exposed to condensate, materials can release these salts and chemicals, staining finishes and causing salt-fed corrosion.

Where there is a risk of condensation, consideration should be given to increasing the protection of materials that are vulnerable to damage from salt laden moisture – such as additional protective coating to fixings and steelwork, and moisture barriers to timber.

B.7.3 Failure of insulation

Within a wall or ceiling the dewpoint will often occur somewhere in the middle of the insulation layer. If the outdoor air has been allowed to infiltrate the wall or ceiling cavity the water vapour it carries will quickly settle out into the blanket. When condensation occurs in insulation, even at levels as low as 1% by volume, it can significantly reduce the effectiveness of the insulation. This is because the insulating air gaps are replaced by water, which is a better conductor of heat than the air it displaces. This reduction in thermal performance is likely to compound the condensation problem. The wet insulation can saturate adjacent materials, leading to mould growth and deterioration of the building fabric.

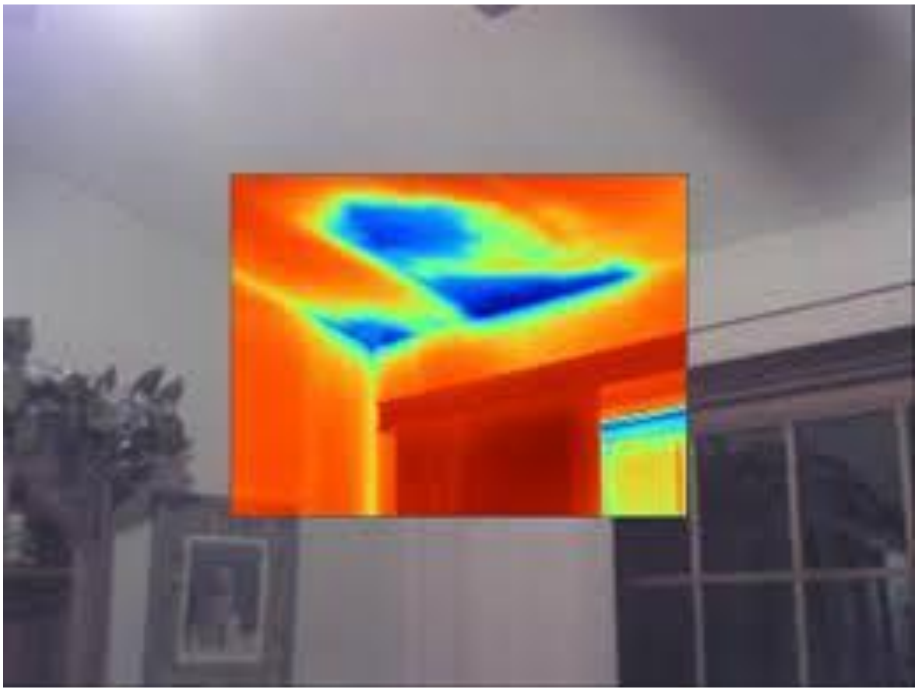


Figure 12 Thermal image showing localised failure of ceiling insulation due to presence of moisture in insulation

B.7.4 Phantom leaks

When moisture unexpectedly turns up in a building there is a tendency to assume it is a building or services leak. However, leaks are not always to blame and problems may be the result of condensation. Condensation may be forming on air conditioning equipment or pipework, or on some other element that is tracking the cold of the air conditioned environment to somewhere in contact with outdoor air.

If the appearance of phantom leaks is seasonal and not directly correlated to periods of heavy rainfall, it is a sign that condensation may be the cause, as condensation may be forming in one location and dripping or running to another location where it becomes apparent.

B.7.5 Surface condensation

Surface moisture will form anywhere warm moist air comes into contact with a cooled surface – i.e. any surface inside an air conditioned space and any poorly insulated material that passes from inside to outside. At its worst this will lead to progressive deterioration of the building. At best it will likely result in puddles of water that have to be managed before they become a safety hazard.

B.7.6 Electrical safety hazard

Condensation can create an electrical hazard when moisture is allowed to form on or collect in an electrical fitting. This could result from the electrical fitting itself being cooled and causing condensation, or it could be that the fitting is downstream from a condensation source which runs toward or into the fitting. This most often occurs when a fitting is exposed to cold, conditioned air. Examples of electrical hazards caused by condensation include:

- Smoke or heat sensors giving false alarms because of moisture in the fitting (see figure 13)
- Light fitting diffusers filling with condensate and ripping the entire fitting out of the ceiling.
- Condensate tracking down the inside of a ceiling fan suspension rod and causing the fan motor to short circuit.
- Contact between a fitting and adjacent moist bulk insulation or sarking, creating an electrical hazard.

Figure 13 Condensation within smoke alarms cause false alarms

Figure 14 Moisture trapped inside light fittings is a dangerous consequence of condensation

B.8 Choosing the Right Air Conditioning System

Any project is only as good as the client's briefing of the design team. In the case of air-conditioning, the clearer the client's intentions and expectations about cooling and the way the building will be managed the better suited the equipment can be to deliver the conditions required. Notwithstanding, there are some misconceptions about comfort conditions and the performance and function of air conditioning systems in hot humid climates.

B.8.1 Requirements

- Air conditioning in humid areas needs to be designed to manage humidity as well as temperature.
- There are times of comparatively low temperatures when the main demand on the system will be the removal of excess water vapour from the air without over-cooling.
- In the tropics, most designers and clients will brief for the air conditioning cooling to control internal areas to 24^{o}C and 50% relative humidity (RH). This is considered standard practice.
- A room temperature of 27^{o}C with increased air movement from ceiling fans may provide an occupant effective temperature equivalent to 24^{o}C.
- A higher indoor temperature set-point may still be comfortable and will allow smaller equipment to be used. This will also reduce running costs and the risk of condensation and mould issues.
- The education and management of staff to accommodate a wider temperature range (including allowing or encouraging staff to dress appropriately) may contribute to the long term realisation of the above benefits.

B.8.2 Capacity

In temperate and dry climates, there is a tendency for designers to over/up size air conditioning equipment with little to no risk from doing so. However, in the humid areas of the Kimberley and Pilbara, oversized air conditioning equipment can be detrimental to the building and its occupants.

It is important for a project's air conditioning requirements to be properly ascertained and for heat load modelling, equipment selection and commissioning to be undertaken to ensure each zone has a suitably sized and properly performing air conditioner.

If the plant capacity is too high, set point temperatures will be reached very quickly at which time the cooling turns off – allowing no further dehumidification. This results in a gradually increasing internal humidity level which creates an uncomfortable environment and creates conditions suitable for mould propagation.

Alternatively if the plant capacity is too low, set point temperatures may not be achieved on an average day and possibly not enough dehumidification will be achieved. Air conditioning plant will also have a harder operating life due to operating at full load for longer periods.

B.8.3 Availability of tradespeople

Many communities in the Kimberley and Pilbara have no refrigeration tradespeople, can experience long delays in supply of spares and at times are separated from larger communities by flood. Even larger communities may lack tradespeople who are qualified to service and repair some of the more sophisticated mechanical services systems available.

When selecting the type of system for a project/site, the availability of suitably qualified tradespeople should be a consideration.

B.8.4 Inverter air conditioners

These are popular because they achieve the desired temperature for the least possible energy input. These variable speed systems operate a lot of the time at well below their peak cooling capacity. The downside of this is that inverters have a reputation for being ineffective at removing moisture from buildings due to the coil temperature being relatively warm..

Under these low-load conditions, the cooling coil's temperature can be close to the air dew point temperature and therefore does not remove significant moisture from the air.

Inverter compressor systems should be carefully selected to ensure that they can still remove moisture when humidity is high and only a few degrees of cooling is needed. This means choosing a smaller unit that works harder rather than a larger unit that never has to operate at peak capacity.

B.8.5 Fixed speed compressors

If you select the wrong fixed-speed air conditioner, you can also end up with poor dehumidification and high space humidity levels. Oversized fixed speed compressors will spend a significant amount of time with the compressor cycled off, when no dehumidification can occur. Slightly under-sizing the compressor will cause the equipment to run longer, more effectively dehumidify the air and provide higher levels of comfort.

B.8.6 Multiple circuit systems

Use multiple circuit systems wherever possible. This improves part load dehumidification provided the evaporator coil is non-interlaced.

B.8.7 A/C equipment detailing

Many elements of an air conditioning system operate at temperatures as low as 12ºC. Any part of the mechanical system where the surface temperature could be below 25ºC is susceptible to condensation. Equipment in roof spaces or non-air conditioned areas needs its own insulated vapour barrier to prevent warm moist air contacting any cold surfaces.

This applies to fan coil units, pipes, ducts, trays, drains, air diffusers, cushion heads and flexible connections.

Generally the most susceptible equipment is the fan coil unit itself and therefore ducted fan coil units should always incorporate a separate insulated safety drip tray below the unit to capture any dripping condensation.

Figure 15

Top: Example of insulated cushion head without vapour barrier, showing signs of water staining.

Bottom: Example of uninsulated safe tray under an uninsulated fan coil unit, which shows evidence of condensation forming on its underside and dripping onto ceiling below.

Figure 16 Corrosion caused by condensation. Insufficient insulation on equipment mounted in a ceiling resulting in condensation and corrosion. This is prevented by adding more insulation to the outside of the cabinet.

B.8.8 Ventilation

All habitable areas need access to outdoor air. This requirement is covered by the building code section F4 for natural ventilation and AS 1668 for mechanical ventilation systems. All occupied spaces fitted with refrigerated air-conditioning need to manage how outdoor air is introduced.

B.8.9 Building pressurisation

Air conditioned buildings need to be pressurised to prevent the uncontrolled ingress of warm humid air. Every building is different so no rule for outdoor air flow rates for building pressurisation works for all buildings. Many buildings can’t be effectively pressurised because air leaks out around doors, windows and through naturally occurring gaps in the building. This reinforces the need for an insulated vapour barrier and testing of its integrity. Only buildings with a fully encapsulating insulated vapour barrier can be effectively pressurised.

B.8.10 Corrosion protection

Coastal areas are continuously exposed to salt spray and salt-laden water. Such exposure, combined with the harsh conditions in the Kimberley and Pilbara, will dramatically reduce the economic life of affected air conditioning equipment. Outdoor equipment should be selected, treated and sited to prevent or delay corrosion.

All outdoor air should be filtered, to ensure that all airborne salt is removed prior to entering the evaporator coil. Special attention needs to be given to reducing the likelihood of outdoor air bypassing the filter and entering the cooling system directly.

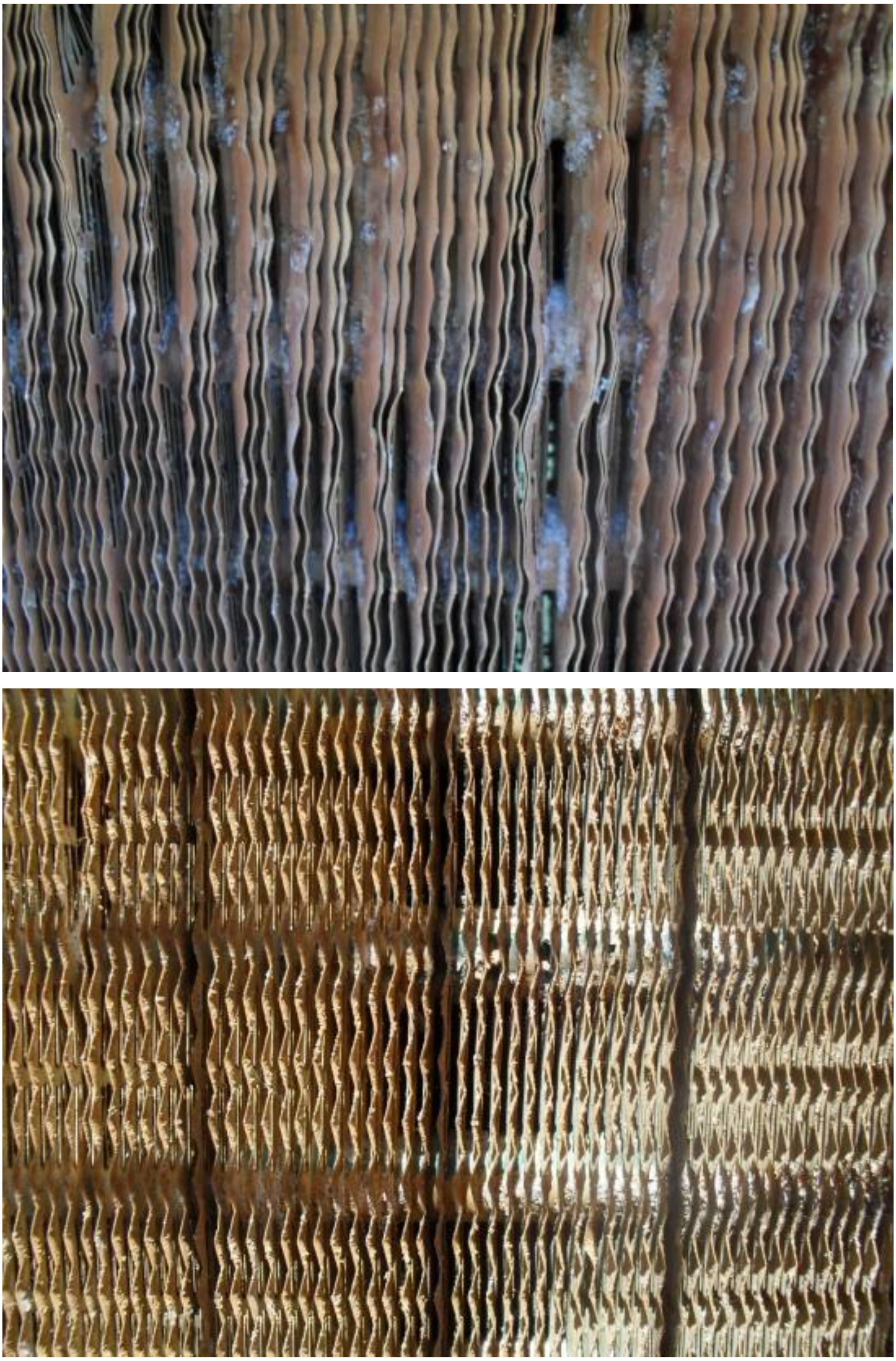


Figure 17: Example of fins with salt deposits on tubes and fins.

B.8.11 A/C air diffusion placement

Cooled air blowing onto any surface can reduce its temperature below dew point and make it susceptible to condensation forming wherever it is contacted by warm moist outdoor air. Correct selection and placement of air diffusion can mitigate this by ensuring the cold air is mixed with room air before it directly contacts any building surface.

B.9 Best Practice Installation and Maintenance

Maintaining high standards of work in regional locations can be challenging due to problems with the supply chain as well as the climate e.g.

- The availability of equipment and spares
- The availability of skilled trades to install and service equipment
- A general (community) acceptance of lower standards of workmanship
- Tradepeoples’ general lack of experience in anything other than conventional domestic building
- The physical difficulties of working in a hot climate
- The difficulty of sealing buildings against wildlife and vermin intrusion.

It is essential that air conditioning equipment is well maintained to extend its life and ensure it can provide the required comfort and dehumidification. To encourage high-quality maintenance, equipment installations should provide easy access, good lighting and uncramped working conditions.

Equipment in the Kimberley and Pilbara needs to be protected from damage caused by fauna that hide/nest within A/C systems and particularly on printed circuit boards.

Figure 18 Cramped position of equipment limits air flow and impedes access for service

PART C. SPECIFIERS' GUIDE

- Provides the technical details and the kind of provisions for HVAC design and building detailing, which, when intelligently incorporated into a competent project design, should deliver a best practice outcome for an air conditioned building in the tropics.

CONTENTS

C.1 Introduction

Important Notice:

In accordance with DoF/BMW policy, there are limited occasions when a proprietary product may be specified and with isolated exceptions, the opportunity for alternative product equal in quality, function etc, to the approval of the client must be offered.

Refer to *MECHANICAL SERVICES CONTRACTOR REQUIREMENTS* Section *C.17.2 Equipment Selections* for additional information.

C.1.1 Intent

The intent of this Part is to:

- Be a guide to preparing specifications to achieve best practice in delivering air conditioned buildings in the Northern Region
- Set out the minimum technical standards needed to meet the air conditioning needs imposed by the Northern Region climate.
- Provide a benchmark for the provision of mechanical building services under the jurisdiction of the BMW within the DoF Northern Region.
- Generally apply to the following specific project types:

    1. **Minor Capital Works**

       Projects requiring design by a registered Engineer; design and administration of new HVAC systems for new or existing systems. Incorporate relevant sections of this specification into the tender documentation.

    2. **HVAC Equipment Replacement**
       (Also referred to as like for like replacement.)

       Replacing air conditioning systems in existing buildings, including upgrading individual elements to meet identified deficiencies. Incorporate relevant sections into the tender documentation.

    3. **BMW Minor Works**

       Projects needing minimal design input. Attach relevant sections of this guide as an appendix to the Request for Quotation documents.

- Supplement (not replace) other relevant documents such as;
    - DoF documents & contracts (including Air Conditioning Issues in Humid Areas),
    - Australian Standards,
    - The Building Code of Australia and
    - State Government agency briefs.
- Deal with specific technical requirements that should be applied including quality of design, detailing and installation. These are presented along conventional discipline/trade demarcations to assist incorporation into project documentation.

C.1.2 Considerations

- The Northern Region encompasses the Pilbara and Kimberley regions of Western Australia. Its geography and seasonally moist, tropical climate dictates the need for specific design, installation and maintenance measures for HVAC systems.
- Each section may be used as a stand-alone performance brief/specification for the design, manufacture and installation of elements of new or existing buildings. However, applying individual components of any section without regard to the remaining related provisions may put at risk the success of any design or installation.
- While each section has been developed to cover a discrete package of work; each is an integral part of the overall guide and should be used in conjunction with the rest of the information.
- Each of the provisions in this section needs to be taken into consideration and intelligently incorporated into the design and construction process.
- This section is not to be treated as providing cut-and-paste solutions.
- Users should obtain appropriate independent professional advice on any specific issues concerning its use.

C.1.3 Exclusions

This is a generic specification guide and is therefore not intended to cover unique or specialist mechanical services systems, such as:

- Centralised direct expansion (DX) multi-zone systems
- Variable Air Volume (VAV) systems
- Variable Refrigerant Volume/Flow (VRV/VRF) systems
- Outdoor air pre-conditioners
- Evaporative cooling
- Chilled/heating water systems
- Specialist gas systems
- Specialist learning areas such as laboratories
- Specialist local ventilation systems

C.2 Design and Construction Strategies

C.2.1 General

Condensation is one of the most serious problems encountered in air conditioned buildings in the tropics. It can lead to building failure, failure of building materials, health impacts on occupants and high operating costs.

It can be extremely difficult and expensive to rectify such problems in a building after it is completed.

The strategies contained in this document will lead to best practice design and construction of buildings and air conditioning systems for tropical areas.

This is not intended to be a definitive or prescriptive set of instructions. Further advice should be obtained from suitably experienced building practitioners with experience in detailing air conditioned buildings in the tropics.

Above all it is imperative that:

- The design team appoints a suitable person from within the project delivery team to champion the tropical aspects of the building through the design, installation and commissioning stages. This includes including sealing, insulation, vapour barriers etc.
- Buildings are designed to keep water and water vapour out of the building envelope, but when it does get in – and it will – enable it to escape. Ignoring this principle causes many moisture-related building problems.
- Extreme care is taken when designing buildings with areas where air conditioning operates 24 hours per day, or where the air-conditioning set point is below 24oC.

C.2.2 Strategies

The following specific strategies need to be applied when designing and building in humid tropical areas.

C.2.2.1 Insulation and Vapour Barriers

- Provide adequate continuous thermal insulation.
- BCA Section J gives minimum insulation R values. However, check the need for additional insulation to prevent condensation. In particular, any space that is required to be cooled below the normal comfort 24°C generally needs thicker insulation.
- Use proprietary systems for insulation installation, such as spacers between the roof and purlins, to prevent excessive squashing of insulation.
- Install a thermal break between external cladding and structural elements that pass from the inside wall surface to the external wall face. This can be incorporated as the building vapour barrier.
- Ensure continuity of insulation to services that pass through the insulation zone including recessed services outlets.
- Minimise outdoor air penetration into the building.
- Install a continuous vapour seal to the full extent of air conditioned areas. Locate the vapour barrier on the warm humid (outside) side of the insulation. **Note that this is the reverse of practice in temperate and colder locations.**

- Fit the walls of air conditioned rooms that adjoin non-air conditioned rooms with insulation and a vapour barrier equivalent to external walls, to prevent condensation forming.
- Pay particular attention to providing a permanent seal where the vapour barrier is penetrated by beams and purlins and where the vapour barrier needs to seal to other building materials.
- Establish a rigorous inspection and rectification regime for installation of both the insulation and vapour barrier.
- Pressure test the building during construction to confirm that a vapour seal has been achieved and rectify any leakage found during testing.
- Where it is difficult to achieve an adequate seal, consider using impermeable or closed cell insulation (such as polystyrene and polyurethane foam) which will be less affected by the presence of moisture.
- Where ceilings have many penetrations for lighting, air conditioning and other services which are difficult to seal, install the vapour barrier and insulation at roof level, not at ceiling level.

C.2.2.2 Materials and Construction Detailing

- Ensure ceiling voids over air conditioned areas are not ventilated.
- Where possible, ensure building finishes inside of the vapour barrier are semi-permeable to permit any condensation occurring within wall and ceiling cavities to dry out e.g.
    - Limit extent of impermeable materials in wet areas.
    - Use acrylic paints.
- Where the risk of condensation cannot be entirely eliminated, increase the durability of materials and protective coatings on at-risk building elements e.g. timber doors and metal door frames.
- Avoid locating electrical fittings under air handling units, condensate trays and condensate or chilled water pipe runs.
- Avoid using recessed fittings where this may compromise the building insulation or vapour seal.
- Fit seals to external doors to air conditioned areas.
- Provide solid core or suitably insulated external doors to minimise condensation and mould forming on the inside of the door. Standard doors do not provide sufficient insulation.
- Avoid pressed metal external door frames or else provide additional corrosion protection.
- Use double-glazed windows to avoid condensation on glass.
- If specifying metal window frames, select those that have insulating conductivity breaker spacers built into the frames.
- Protect equipment and printed circuit boards from nesting wildlife.
- Vermin-proof building elements.

C.2.2.3 Space planning and design

- Avoid placing air conditioned rooms above non-air conditioned or external spaces where practical. It is difficult to properly install floor insulation and vapour barriers for elevated air conditioned rooms that are above non- conditioned spaces. Possible alternatives are insulation above the slab with topping screed or flooring over, or cold room type construction.

- Install an air lock or revolving door at main entry and frequently used entries to air conditioned buildings.
- Locate access to cold room doors in air conditioned areas.
- Access freezers from inside cold rooms.

C.2.2.4 Air conditioning and ventilation

- Size and specify air conditioning units to ensure humidity as well as temperature is managed.
- Set air conditioning temperature at or close to 27ºC.
- Use ceiling fans to increase comfort levels at higher set temperatures.
- Control humidity of conditioned spaces to maintain the indoor dew point at or below 13ºC.
- Partially air condition A/C plant areas to minimise condensation issues. The plant room therefore also needs to be vapour sealed and insulated as for other air conditioned areas.
- Pressurise air conditioned spaces to limit infiltration of outdoor air.
- Condition all outdoor air introduced to the building to remove excess water vapour.
- Locate air conditioning outlets so as to avoid cold air being directed towards windows.
- Locate air conditioning outlets so as to avoid cold air being directed at surfaces that might occasionally come in contact with outdoor air via adjacent doors to outside or into unconditioned spaces.

C.3 Engineering Consultant Responsibilities

C.3.1 General

The engagement of mechanical engineers by BMW, and minor capitals works design and administration projects, should be in accordance with the BMW Engineering and Hydraulic Services Panel.

Relevant sections of this guide should be incorporated into any mechanical engineering design consultancy specification in the Northern Region.

HVAC Equipment Replacement projects do not generally require a design however where a design is required, it should comply with the requirements of Minor Capital Works as above.

C.3.2 Consultant Deliverables

Consultants are responsible for undertaking the following work:

- Due diligence reporting (for existing sites and HVAC equipment replacements)
- Schematic design report consisting of drawing/s and report
- Design development report consisting of drawing/s, report and equipment schedules
- Tender documentation in formatting consistent with BMW tendering protocols, incorporating all relevant sections of this specification.
- Reporting at appropriate stages of construction (where engaged to carry out contract administration).

Documentation must also comply with the Engineering and Hydraulic Services Panel contract requirements.

C.3.3 Minor Capital Works

Incorporate the actions listed below into the design and contract documentation for locations where the ambient wet bulb design temperature is above the building dry bulb design temperature. Where BMW or the Department does not supply a building dry bulb design temperature; use 24^{o}C db.

- Identify zone/s within building/s that require insulated vapour barriers, based on dew point and the risk of condensation occurring.
- Liaise with project manager to establish the location and extent of building insulated vapour barrier needed. The generally preferred location of the insulated vapour barrier is on the underside of the roof and continuous down to the floor/slab; in the case of elevated floors, on the underside of the underfloor insulation system.
- Identify the systems, ducts, light fittings and air diffusion that need to be designed according to this specification.
- Inspect and report on the suitability of installed insulated vapour barriers during the construction and contract administration phase of the project.

C.3.4 HVAC Equipment Replacement

For all HVAC equipment replacements, inspect the site and carry out due diligence reporting, complying with the Minor Capital Works requirements where appropriate.

C.3.4.1 Due Diligence Reporting

Include the following elements in a due diligence report:

- Site description
- Existing air conditioning (including a schedule of all air conditioning on the site or as advised by the local BMW representative)
- Air conditioning recommendations and budgets (based primarily on economic life but should also consider economics of scale and remoteness of the site location)
- Vapour barriers (existence and condition of the vapour barrier and any damp/mould issues in the building and other building elements that may require specific consideration)
- Existing building recommendations
- Recommendations

C.3.5 Design Drawings

Provide design drawings for all consultant-designed projects. Drawings must:

- Comply with DoF/BMW CADD Protocols for Contract Deliverables (refer here)
- Describe the services and their relationship with other building components
- Be more than single-line drawings.

Supply design drawings to the mechanical services contractor in AutoCAD .dwg format for use in the shop and as-constructed drawings. The contractor is responsible for the dimensional accuracy of the shop and as-constructed drawings.

C.3.6 Specification

C.3.6.1 General

Include any clauses from this document that may be relevant to the project.

C.3.6.2 Maintenance and Servicing

A maintenance and service schedule should take into account the difficulties of visiting remote sites and the fact that many sites will have higher maintenance requirements due to their harsh environments.

The specification should state the number of maintenance/service visits allowed for during the 12 months defects liability/maintenance period, with reference to the remoteness of the site, specific environmental factors and the installed equipment.

For sites located within 10km of the coast, specify cleaning of the condenser coils with fresh or distilled water every six months.

C.3.6.3 Equipment Schedules

Provide detailed equipment schedules for each piece of specified equipment including, as a minimum for air conditioners:

- Designation
- Supply air quantity………………………………………………………... (litres per second)
- Outdoor air quantity……………………………………………………… (litres per second)
- Estimated static pressure (minor split systems exempted) ………………..... (Pascals)

- Total cooling capacity …………………………………………………………(kilowatts)
- Sensible cooling capacity……………………………………………………..(kilowatts)
- Coil entering conditions ..……………………………………………………(oCdb/oCwb)
- Coil leaving conditions …………………………………………………….(oCdb/oCwb)
- Ambient conditions ……………………………………………………………… (oC db)
- Electrical power supply………………………………………………………….. (V/ph/Hz)
- System current draw ……………………………………………………………...(amps)
- Fuse/breaker size …………………………………………………………………(amps)
- Nominal selection ………………………………………………….. (make and model)
- Comments (including considerations such as condenser coil treatment and pcb treatments)

C.3.6.4 Defined Contractor Deliverables

Include the following contractor requirements in the specification:

- Detailed equipment selections/schedules
- Shop drawings
- Commissioning data
- As-constructed drawings
- Operating and maintenance manuals
- Staff training and handover visit
- Completed service reports.

C.4 Design Requirements

C.4.1 General

The following design requirements apply to the mechanical services design for all project types including minor capital works, HVAC equipment replacement and BMW minor works. Where an engineering consultant is not engaged, BMW should apply relevant sections of this guide to the projects specifications.

C.4.2 Heat Loads

Calculate heat loads using the latest version of ACADS BSG CAMEL (Carrier Method of Estimating heat Loads) in accordance with the AIRAH Application Manual *DA9 Load Estimation and Psychrometrics*. Design the air conditioning to achieve the required indoor conditions, using the Ambient Conditions table for locations in the Kimberley and Pilbara regions below.

C.4.2.1 Indoor Conditions

Design for the following indoor conditions:

- 22.5 +/- 1.5^{o}C (or 24^{o}C for cooling design)
- 50% relative humidity indirectly controlled by coil selection; 65% for high occupancy areas.

Consider achieving an effective temperature of 24^{o}C by combining a design temperature up to 27^{o}C with air movement e.g. ceiling sweep fans. This will reduce plant size, running costs and prevalence of condensation and mould issues.

Nominate the area, occupancy, lighting allowance and electrical heat load allowance for each air conditioned space at each phase of the design, and include this in the tender documentation for future reference.

C.4.2.2 Ambient conditions table for the Kimberley and Pilbara

Location	Ambient Design Conditions ^{o}C db / ^{o}C wb		
	Comfort	Critical	Winter
Broome	37.4 / 28.5	39.4 / 28.5	15.4
Broome (Cape Leveque)	33.7 / 28.8	34.2 / 29.4	19.8
Broome (La Grange Mission)	37.8 / 29.1	40.4 / 29.8	15
Canarvon	35.0 / 25.6	38.4 / 27.1	9.4
Derby	38.8 / 28.1	42.8 / 28.2	10.5
Derby (Cockatoo Island)	33.7 / 27.7	35.1 / 28.7	21.3
Derby (Koolan Island)	34.2 / 27.7	35.9 / 29.5	20.2
Fitzroy Crossing	42.0 / 26.9	41.9 / 28.3	15.1
Goldsworthy	43.5 / 26.9	45.4 / 28.0	15.6
Halls Creek	41.0 / 24.5	41.7 / 25.2	13.9
Halls Creek (Turkey Creek)	41.6 / 25.8	43.4 / 28.0	15.5
Kalumburu	37.9 / 28.2	39.6 / 28.7	14.9
Kalumburu (Mitchell Plateau)	36.9 / 26.7	38.2 / 28.5	15.8
Karratha	38.9 / 27.6	42.6 / 29.0	15
Kununurra	40.3 / 27.3	41.3 / 27.7	18.1
Kuri Bay	35.1 / 27.6	36.3 / 28.4	20.2
Learmonth	41.9 / 25.9	43.6 / 27.2	11.3
Mandora	39.6 / 29.1	42.0 / 30.0	15
Marble Bar	44.6 / 25.8	46.2 / 26.5	13.4
Mardie	41.0 / 27.6	43.9 / 28.6	12.6
Newman	41.2 / 23.1	43.0 / 27.6	8.1
Onslow	40.4 / 27.6	45.3 / 28.0	12.5
Port Hedland	39.5 / 28.0	41.2 / 29.0	14.4
Roebourne	42.6 / 27.8	44.5 / 27.8	15.2
Wyndham	41.8 / 27.5	43.7 / 27.9	18.8

Areas with a winter ambient design condition above 15^{o}C do not require provisions for heating unless either:

- The site is occupied 24h/day or
- It is specifically requested by BMW or the Department.

C.4.3 Building Pressurisation and Outdoor Air

C.4.3.1 General

Building pressurisation is achieved by forcing more outdoor air into the building than exhaust air is being drawn out.

It is necessary to pressurise air conditioned spaces with conditioned outdoor air to prevent moisture entering the building as it leads to high running costs and low effectiveness of air conditioning, condensation at building openings and growth of mould and mildew.

The BCA section F4 allows mechanical outdoor air systems to be omitted if a space is naturally ventilated via operable doors and/or windows. Whilst this is suitable for mild climates, it is not suitable where building pressurisation is required nor does it address the Northern Region's specific issues.

Inspect the building to identify if there are any problems associated with the ingress of ambient air, and whether the building needs to be pressurised to reduce them.

Pressurisation may not be needed in HVAC equipment replacement projects where the existing unpressurised room/building A/C system was operating successfully without it.

If pressurisation is required, equipment and processes must meet the following requirements.

C.4.3.2 Outdoor Air

- Pressurise buildings using outdoor air in locations where the design ambient wet bulb temperature exceeds the building dry bulb design temperature.
- Comply with AS1668.2 regarding the provision of mechanically assisted outdoor air to suit occupancy.

C.4.3.3 Dedicated Outdoor Air Systems

- Refer to ACIHA Appendix 6 for preamble and design recommendations for dedicated outdoor air systems.
- Competent designers should assess the suitability of such system/s for each project based on requirements for outside and exhaust air, ambient conditions and remoteness of the site.

C.4.3.4 Outdoor Air and Exhaust Air

- Where a room or building contains an exhaust air system, design the outdoor air systems to exceed the total exhaust air rate by the greater of 10% or 50 L/s per external door.
- Intermittently operated exhaust systems are exempt from this clause.

C.4.3.5 Exhaust Discharge Louvres

- Incorporate accessible non return dampers into all discharge louvres shall to prevent building pressurisation and ingress of airborne material during a cyclone.

C.4.3.6 Outdoor Air Louvres

- For all outdoor air louvres with a face area of greater than 0.5 m^2 incorporate a motorised damper that will shut automatically when the associated A/C system is de-energised. Damper to be spring return closed.
- Where designing A/C systems required to operate during cyclone conditions, consider including such measures as an outdoor air cowl on top of a filter plenum, or through a roof, with a remotely switched motorised damper.

C.4.4 Systems Selections

C.4.4.1 General

The selection of the most appropriate system should be guided by the list below, which is graded in order of preference. When choosing a system, select the one that has the highest rating and is most appropriate for its purpose.

1. Split ducted systems with indoor unit located in dedicated indoor airtight plant areas
2. Packaged ducted systems
3. Split ducted systems with indoor unit located in a vapour tight roof void
4. Cassette/Under ceiling split systems
5. Wall hung split systems

C.4.4.2 HVAC Equipment Replacements

Never replace an existing system with one which is lower in the preference list - e.g. an existing split ducted system should not be replaced with wall hung split systems.

C.4.5 Building Design and Insulated Vapour Barriers

C.4.5.1 General

Most coastal locations in the region require installation of an insulated vapour barrier because the ambient air dew point frequently exceeds internal design conditions. The following requirements must be met:

C.4.5.2 Existing Buildings

Identify if a building vapour barrier exists. Notify BMW in writing if:

- the building does not have an insulated vapour barrier;
- an existing insulated vapour barrier is compromised or non-functional; or
- it is not possible to establish the determine of an insulated vapour barrier.

C.4.5.3 New Buildings

Identify the extent of the building that requires an insulated vapour barrier and ensure that the architect/building designer is aware of the requirement.

Only use recessed light fittings when the void space dew point is guaranteed to exceed 23°C.

C.4.6 Placement of External Plant

C.4.6.1 General

The premature failure or poor performance of condensers, condensing units and external packaged units is frequently caused by poor design and/or maintenance of the external plant spaces. Factors such as sun exposure, proximity of plants, soaking from bore reticulation systems and physical damage will all reduce the life expectancy and efficiency of such systems.

- Where possible, orient condenser coils so they are protected from direct sunlight and so prevailing winds do not stall the condenser fans. Mount coils in an accessible location at ground level, above any flooding risk.
- Locate all external equipment either in lockable plant areas or protected from vandalism by proprietary hot dipped galvanised lockable secure cages with a solid top shade panel.
- Locate all external plant so as to avoid hot air discharge impacting on other plant and adjacent building features and to minimise the risk of hot air recycling.
- Also refer to DoF BMW publication *Design for Maintenance Minimisation*, Part E, section Location and Access.

C.4.6.2 Roof Mounted Equipment

- Only locate external plant on top of the roof of a building if the roof is safely trafficable and has a pitch of less than five degrees. Place the plant on a platform to avoid roof damage during servicing.
- Secure any roof-mounted equipment to roof purlins using stainless steel guy wires and all stainless steel fixings, to protect it from cyclones.
- Mount the feet of all external units on waffle pads or equivalent anti-vibration mounts.

C.4.6.3 Wall Mounted Condensers/Condensing Units

- The underside of external units mounted on gallows brackets should be between 300 and 1500 mm above ground level. Locate away from trafficable areas such as pedestrian verandas to avoid the dangers posed by exposed raw ends of Uni-strut type brackets.
- Mount the feet of all external units on waffle pads or equivalent anti-vibration mounts.

C.4.6.4 Concrete Slab/Plinth Mounted Condensers/Condensing Units

- Where units are located on concrete plinths, locate plinths away from risk of flood. The plinth to be 100m above finished local ground level and to extend 900mm beyond the footprint of the unit.
- Locate horizontal discharge condensing units a minimum of 200mm from any adjacent wall or condensing unit. Mount units on proprietary mounting feet a minimum 100mm in height.
- Mount packaged units or vertical discharge condensing units on 250mm high concrete strip plinths on top of the concrete plinths.
- Mount the feet of all external units on waffle pads or equivalent anti-vibration mounts.

C.4.7 VRV/VRF Systems

Unless directed otherwise, do not design for or install VRV/VRF type systems in areas with an urban population fewer than 10,000 as there is unlikely to be appropriately trained and experienced service people available. For towns with a population over 10,000, limit the use of VRV/VRF systems to within a 100km radius of the town centre.

C.4.8 Painting

C.4.8.1 General

Paint all exposed mechanical services in situ on site. This includes all associated supports, brackets, clamps etc.

Do not paint equipment with UV resistant finishes or which is factory powder coated

Paint systems and application processes must meet the following requirements.

C.4.8.2 Sites within 10km of the Coast

- A three coat application with one primer coat and two finishing coats applied by roller and brush. Allow at least eight hours at recommended environmental conditions between coats.
- Carry out all painting in accordance with manufacturer’s recommendations.
- Primer coat: Dulux Duremax GPE Zinc Phosphate PC215, or approved equivalent alternative, to a dry film thickness of 100 to 200 microns.
- Second coat: Dulux Duremax GPE PC255 (mid grey only), or approved equivalent alternative, to a dry film thickness of 100 to 200 microns.
- Top coat: Dulux Luxachlor Finish PC 524, or approved equivalent alternative, to a dry film thickness of 40 to 60 microns. Apply additional coats as required to achieve specified colour opacity.

C.4.8.3 Sites Greater than 10km of the Coast

- A three coat application with one primer coat and two finishing coats. Each coat applied by roller and brush to a dry film thickness of 25 to 30 microns. Allow at least two hours at recommended environmental conditions between coats.
- Carry out all painting in accordance with manufacturer’s recommendations.
- Primer coat: Dulux Quit Rust Etch Primer, or approved equivalent alternative.
- Second coat: Dulux Weathershield X10 Gloss Acrylic, or approved equivalent alternative.
- Top coat: Dulux Weathershield X10 Gloss Acrylic, or approved equivalent alternative.

C.5 Equipment Requirements

C.5.1 General

These requirements are specific to Northern Region, and are in addition to general good practice and compliance with relevant standards.

- All units to be cooling only, unless otherwise stipulated by BMW or the design requirements in this specification.
- Anti-corrosion provisions only relate to a coastal environment i.e. within 30 km of the coast, unless otherwise specified.
- This specification uses systems commonly found throughout the Northern Region, including:
  - ducted packaged air conditioning systems;
  - ducted split commercial systems;
  - ducted split inverter compressor systems; and
  - wall hung/ceiling cassette/under ceiling suspended split inverter systems.

The following requirements must be met.

C.5.2 Ducted Packaged Air Conditioning Systems

C.5.2.1 General

- Use packaged air conditioning units manufactured by Specialized Engineering or Comm Air, or approved equivalent alternative units with local support and demonstrated availability of spares and service in the local area.
- The manufacturer must have at least one designated service agent in Broome and a parts distribution warehouse in metropolitan Perth with full availability of spares.
- Units to be fully self-contained. Provide flexible connections to all duct connections onto the unit.
- Replace all standard screws, bolts and fasteners with equivalent stainless steel items. Protect all uncoated exposed components with epoxy coating or similar to make them suitable for use in a high salinity environment.
- Only use self-tapping screws into nylon inserts and where they don’t break metal coatings.
- Where size of unit allows, use dual refrigerants circuits on all installations located more than 100km from a population centre of more than 10,000 people, due to the limited availability of appropriate service people in remote areas.
- Systems to be capable of continuous operation in ambient temperatures up to 53^{o}C.
- Ensure electrical phase failure protection is factory fitted to each three phase unit.

C.5.2.2 Unit Casing

- Construct the packaged unit casing from a minimum of 1.2 mm sides and 1.6 mm base galvanised sheet steel, and finish with a polyester powder coat. Only carry out the powder coating process once all cutting, punching and folding is completed, to ensure that all surfaces are suitably protected from corrosion.
- Powder coating to be capable of withstanding 500 hours salt spray in accordance with ASTM B-117.

C.5.2.3 Condenser Coil

Design coils to ensure uniform airflow and low temperatures and operating pressures when operating under extreme conditions. Fins to be mechanically bonded to the coils.

- **Within 5km of the coast:**
  - Coils to be copper tube, copper fin or approved alternative.
- **Between 5km and 30km from the coast:**
  - Coils to be copper tube, aluminium fin type coils with a Heresite, Coilcoat, or approved equivalent alternative, post-manufacture anti corrosion treatment.
- **More than 30 km from the coast:**
  - Coils to use standard factory-applied anti corrosion treatment.

C.5.2.4 Condenser Fans

- Use sickle type fans with glass reinforced coatings to provide corrosion protection and UV resistance. Use stainless steel fasteners.
- Incorporate head pressure control using either speed controllers or fan cycling.
- Do not use motors with integral printed circuit boards.

C.5.2.5 Compressors

- Fit compressors with independently-powered electric sump/crank case heaters which are thermostatically controlled, to automatically regulate the crank case temperature.
- Provide soft starters on compressor motors rated above 4kW electrical input, or if otherwise required to alleviate against voltage drop or meet local regulations.

C.5.2.6 Evaporator Coils

- Incorporate a sloping stainless steel drip tray designed to limit air bypass and capture all condensate from the evaporator coil.

C.5.2.7 Electrical and Controls

- House all controls, except remote switching and temperature sensing, within the unit switchboard.
- Controls to be 24V, fed from the unit's 240V external supply.
- **Minimum control features for all A/C systems:**

  1. Manual *on*, with adjustable, eight-hour run-on, limited duration, time clock controller with neon run indicator
  2. Manual *off*
  3. Programmed to automatically turn itself off at least twice a day, at adjustable times
  4. Averaging of two temperature sensors
  5. Automatic lock-out on failure with reset by interruption of power supply
  6. Automatic restart after power failure
  7. All safety controls in circuit when items are on test
  8. High and low pressure cut-outs to de-energise compressors in the event of excessively high or low refrigerant pressures
  9. Permanent power to crank case heaters

10. A master controller with a separate, secondary controller in the air-conditioned space that can be disabled if required.

- For HVAC equipment replacements, reuse the existing power supplies where possible, and provide a new weatherproof isolator that is fixed to the A/C unit housing.

C.5.2.8 Refrigerant

- Use R410A or R134A as appropriate for the system configuration. Ensure the unit is factory charged with the required capacity of refrigerant for the designed application.

C.5.2.9 Filter

- Filters to be/have:
  - Disposable, (approximately) 100mm thick units achieving a performance characteristic of F5 filtration in accordance with AS 1324.1 2001
  - Pleated glass fibre mounted in a rigid stainless steel frame with a foam rubber seal and stainless steel clips to prevent air bypass.
  - An initial clean pressure drop of less than 50 Pa and a filter face velocity of less than 1.5 m/s.
- Higher grade filters may be specified at the discretion of the engineering consultant.
- Electrostatically charged filters will not be accepted as an alternative.
- Slide withdrawal filters will not be accepted as an alternative.
- Provide a magnahelic gauge on the return air plenum to indicate the pressure drop across the filter bank, clearly indicating the operating range of the filters and when they require changing.

C.5.3 Ducted Split Commercial Systems

C.5.3.1 General

- Use ducted split air conditioning units manufactured by Temperzone, Actron Air, or approved equivalent alternative units with local support and demonstrated availability of spares and service in the local area.
- The manufacturer must have at least one designated service agent in Broome and a parts distribution warehouse in metropolitan Perth with full availability of spares.
- Provide flexible connections – insulated where necessary - to all ducts and connections onto the fan coil unit.
- Where size of unit allows, use dual refrigerants circuits on all installations located more than 100km from a population centre of more than 10,000 people, due to the limited availability of appropriate service people in remote areas.
- Systems to be capable of operating continuously in ambient temperatures up to 53^{o}C.
- Ensure electrical phase failure protection is factory fitted to each three phase unit.
- See Appendix A for specific details.

C.5.3.2 Fan Coil Unit Casing

- Access panels to have foam rubber gasket seals and stainless steel fasteners.
- If the fan coil unit is located within the building roof space, in addition to the internally insulated or twin skin cabinet construction, externally insulate the entire unit with two

layers of 12 mm Armaflex, or approved equivalent alternative. Stagger joints in alternate layers.
- Provide an insulated stainless steel safety drip tray below the fan coil unit, with a minimum 100 mm clearance. To be insulated on the five external surfaces with two layers of 12 mm thick Armaflex, or approved equivalent alternative, with all joins overlapped and glued. Provide each safety tray with a separate drain point located in a position where its operation is visible to the user.
- Insulate flexible connections with two layers of 12 mm Armaflex, or approved equivalent alternative. Stagger joints in alternate layers.

C.5.3.3 Condensing Unit Casing

- Construct the unit casing from a minimum of 1.2 mm sides and 1.6 mm base galvanised sheet steel and finish with a polyester powder coat. Only carry out the powder coating process out once all cutting, punching and folding is completed, to ensure that all surfaces are suitably protected from corrosion.
- The powder coating to be capable of withstanding 500 hours salt spray in accordance with ASTM B-117.
- Replace all standard screws, bolts and fasteners with equivalent stainless steel units. Epoxy coat uncoated exposed components to make them suitable for use in a high salinity environment.
- Self-tapping screws shall only be used into nylon inserts to avoid coating damage.

C.5.3.4 Evaporator Coil

- Use non-interlaced cooling coils on dual compressor units in humid environments so as to provide better dehumidification at part load conditions.
- Incorporate a stainless steel drip tray designed to limit air bypass and capture all condensate from the evaporator coil. Drain the drip tray to waste via a trapped PVC/copper waste to a suitable location.
- Insulate the condensate drain to the point of discharge from the building with 25 mm Armaflex, or approved equivalent alternative insulation.

C.5.3.5 Fan Coil Supply Air Fan

- Select fans in accordance with the equipment schedule which will deliver the supply air quantity against the calculated system pressure drop with 50% plugged filters.
- Single phase fans to incorporate multiple speed tapings. Three phase fans to be belt driven with multiple drive belts. The contractor to allow for carrying out a belt and pulley changes to achieve the design air quantities.
- Cable tie a matched spare set of belts within the return air/mixed air plenum.

C.5.3.6 Condenser Coils

- Design coils to ensure uniform airflow, and low temperatures and operating pressures when operating under extreme conditions. Fins to be mechanically bonded to the coils
- **Within 5km of the coast:**
    - Coils to be copper tube, copper fin or approved alternative.
- **Between 5km and 30km from the coast:**

  - Coils to be copper tube, aluminium fin type coils with a Heresite, Coilcoat, or approved equivalent alternative post-manufacture anti-corrosion treatment.
- **More than 30 km from the coast:**
  - Coils to use standard factory-applied anti-corrosion treatment.

C.5.3.7 Condenser Fans

- Fans to be sickle type with glass-reinforced coatings for corrosion protection and UV resistance. Fans to have stainless steel fasteners.
- Incorporate speed controllers or fan cycling to control head pressure control Do not use motors with integral printed circuit boards.

C.5.3.8 Compressors

- Fit compressors with permanently powered electric sump/crank case heaters. Heaters to be thermostatically controlled to automatically regulate the crank case temperature.
- Provide soft starters on compressor motors rated at greater than 4kW electrical input, or when dictated by voltage drop considerations or local regulations.

C.5.3.9 Electrical and Controls

- Controls to be 24V fed from the unit’s from the external 240V supply.
- **Minimum control features for all A/C systems:**
  1. Manual *on*, with adjustable, eight-hour run-on, limited duration, time clock controller with neon run indicator
  2. Manual *off*
  3. Programmed to automatically turn itself off at least twice a day, at adjustable times
  4. Averaging of two temperature sensors
  5. Automatic lock-out on failure with reset by interruption of power supply
  6. Automatic restart after power failure
  7. All safety controls in circuit when items are on test
  8. High and low pressure cut-outs to de-energise compressors in the event of excessively high or low refrigerant pressures
  9. Permanent power to crank case heaters
  10. A master controller with a separate, secondary controller in the air-conditioned space that can be disabled if required.
- For HVAC equipment replacements, reuse the existing power supplies where possible, and provide a new weatherproof isolator that is fixed to the A/C unit housing.

C.5.3.10 Refrigerant

- Use R410A or R134A as appropriate for the system configuration. Ensure the unit is to be factory charged with the required capacity of refrigerant for the designed application.

C.5.3.11 Filters

- Filters to be/have:
  - Disposable, (approximately) 100mm thick units achieving a performance characteristic of F5 filtration in accordance with AS 1324.1 2001.

    - Pleated glass fibre mounted in a rigid stainless steel frame with a foam rubber seal and stainless steel clips to prevent air bypass.
    - An initial clean pressure drop of less than 50 Pa and have a filter face velocity of less than 1.5 m/s.
- Higher grade filters may be specified at the discretion of the engineering consultant.
- Electrostatically charged filters will not be accepted as an alternative.
- Slide withdrawal filters will not be accepted as an alternative.
- Provide a magnahelic gauge on the return air plenum to indicate the pressure drop across the filter bank, clearly indicating the operating range of the filters and when they require changing.

C.5.4 Ducted Split Inverter Air Conditioning Systems

C.5.4.1 General

- Use ducted split inverter air conditioning units manufactured by Daikin, Toshiba, or approved equivalent alternative, with local support and demonstrated availability of spares and service.
- The manufacturer must have at least one designated service agent in Broome and a parts distribution warehouse in metropolitan Perth m with full availability of spares.
- Provide insulated flexible connections to all duct connections onto the fan coil unit.
- Systems to be capable of operating continuously in ambient temperatures up to 53ºC.
- See Appendix A for specific details.

C.5.4.2 Fan Coil Casing

- Access panels to have foam rubber gasket seals and stainless steel fasteners.
- If the fan coil unit is located within the building roof space, in addition to the internally insulated or twin skin cabinet construction, externally insulate the entire unit with two layers of 12 mm Armafle, or approved equivalent alternative. Stagger joints in alternate layers.
- Provide an insulated stainless steel safety drip tray below the fan coil unit with a minimum 100 mm clearance and 19 mm Armaflex, or approved equivalent alternative insulation glued to the underside and edges with glued joins. Provide each safety drip tray with a separate drain point located in a position where its operation is visible to the user. Insulate flexible connections with two layers of 12 mm Armaflex, or approved equivalent alternative. Stagger joints in alternate layers.

C.5.4.3 Evaporator Coil

- Ensure the coil incorporates a proprietary drip tray designed to limit air bypass and capture all condensate from the evaporator coil. Drain the drip tray to a suitably located waste via a trapped PVC/copper waste.
- Insulate the condensate drain with 25 mm Armaflex, or approved equivalent alternative, to the point of discharge from the building.

C.5.4.4 Outdoor Units

- Replace all standard fixings with equivalent stainless steel units. Epoxy coat (or equivalent) all uncoated exposed components to make them suitable for use in a high salinity environment.
- Condenser fans to be:
  - UV and corrosion resistant sickle type units
  - Statically and dynamically balanced.
- The condensing unit control panel/circuit boards to have an IP Rating of minimum IPX4 (nominally IP54).
- Coat printed circuit boards (PCBs) within the condensing unit with a silicone based coating (in addition to the manufacturer’s coating) to prevent damage from insects/lizards. Use Electrolube SRC, or approved equivalent alternative coating, applied to ensure correct operation of all terminals on the PCB.
- Condenser coil to be aluminium fin, copper tube construction, treated with suitable anti-corrosion treatments:
  - A factory-applied hydrophilic film over a corrosion resistant acrylic resin
  - For sites less than 30km from the coast, apply an additional coating of Heresite VR-500, or approved equivalent alternative.
- Replace all standard fixings with equivalent stainless steel units.
- The compressor to be an inverter driven scroll compressor, to allow infinite modulation of capacities to match the required indoor heating/cooling capacities, with a minimum five year manufacturer’s warranty.

C.5.4.5 Electrical and Controls

- Each condensing unit to have its own integral electrical switchboard, fully factory wired and housed within a weatherproof enclosure.
- Earth all electrical components to a common earth bar.
- Run all electrical cabling in cable trays or conduits, colour code cables.
- Ensure unit current draw will not exceed that nominated in the equipment schedule within this specification.
- House all controls - excluding remote switching and temperature sensing - within the unit switchboard. Controls to be 24V, fed from the unit’s external 240V supply.

  1. Minimum control features: Seven day programmable time clock
  2. Automatic lock-out on failure with reset by interruption of power supply.
  3. Automatic restart after power failure
  4. All controls in safety mode when items are on test
  5. High and low pressure cut-outs to de-energise compressors in the event of excessively high or low refrigerant pressures
  6. Permanent power to crank case heaters
  7. Automatic change-over relay circuits for reverse cycle heating.
  8. Automatic reverse cycle defrost cycle with indoor and outdoor fans turned off
  9. All safety controls, safety interlocks, test switches, and time delays to be in accordance with modern best practice.

C.5.4.6 Refrigerant

- Use R410A. Ensure the unit is to factory charged with the required quantity of refrigerant for the designed application. Refrigerant expansion to take place at the condenser if required by the system layout.

C.5.4.7 Filters

- Filters to be/have:
    - Disposable, (approximately) 100mm thick units achieving a performance characteristic of F5 filtration in accordance with AS 1324.1 2001.
    - Pleated glass fibre mounted in a rigid stainless steel frame with a foam rubber seal and stainless steel clips to prevent air bypass.
    - An initial clean pressure drop of less than 50 Pa and have a filter face velocity of less than 1.5 m/s.
- Higher grade filters may be specified at the discretion of the engineering consultant.
- Electrostatically charged filters will not be accepted as an alternative.
- Slide withdrawal filters will not be accepted as an alternative.
- Provide a magnahelic gauge on the return air plenum to indicate the pressure drop across the filter bank, clearly indicating the operating range of the filters and when they require changing.

C.5.5 Minor Split Air Conditioning Systems

C.5.5.1 General

- Use Daikin, Toshiba, or approved equivalent alternative split system units, either cassette, wall hung or under-ceiling type as appropriate.
- The manufacturer must have at least one designated service agent in Broome and a parts distribution warehouse in metropolitan Perth with full availability of spares.

C.5.5.2 Outdoor Unit

- Replace all standard fixings with equivalent stainless steel units. Coat uncoated exposed components with epoxy or similar to make them suitable for use in a high salinity environment.
- Condenser fan /s shall be UV resistant and corrosion resistant sickle type units and shall be statically and dynamically balanced.
- The condensing unit control panel/circuit boards to have an IP Rating of minimum IPX4 (nominally IP54).
- Coat printed circuit boards (PCBs) within the condensing unit with a silicone based coating (in addition to the manufacturer’s coating) to prevent damage from insects/lizards. Use Electrolube SRC, or approved equivalent alternative coating, applied to ensure correct operation of all terminals on the PCB.
- Condenser coil to be aluminium fin, copper tube construction, treated with suitable anti-corrosion treatments:
    - A factory-applied hydrophilic film over a corrosion resistant acrylic resin
    - For sites less than 30 km from the coast, apply an additional coating of Heresite VR-500, or approved equivalent alternative.

- Replace all standard fixings with equivalent stainless steel units.
- The compressor to be an inverter driven scroll compressor, to allow infinite modulation of capacities to match the required indoor heating/cooling capacities, with a minimum five year manufacturer's warranty.
- Replace all standard fixings with equivalent stainless steel units.
- The compressor to be an inverter driven scroll compressor, to allow infinite modulation of capacities to match the required indoor heating/cooling capacities, with minimum five years manufacturer's warranty

C.5.5.3 Indoor Unit

- The supply air fan to driven by a speed-controlled motor.
- Include additional insulation when using ceiling recessed cassette type fan coil unit, as follows:
  - provide additional insulating blocks at the unit/ceiling junction;
  - provide additional insulation to the entire fan coil unit casing, using two layers of 12mm Armaflex, or approved equivalent alternative, glued to the outside of the casing. Stagger joints in alternate layers.

See Appendix A for specific details.

C.5.5.4 Electrical and Controls

- Provide a single 240 Volt 50 Hz single phase power supply to the outdoor unit.
- Controls shall be proprietary hard wired or infra-red remote controllers with the following functions:
  1. Air conditioning mode selection
  2. Seven day programmable time clock
  3. Fan speed adjustment
  4. Temperature set point adjustment
  5. Limited duration override of time clock control
  6. Fault reporting
- For public building, use hardwired LCD display controllers with remote temperature sensors with the controller not accessible to the public.

C.5.6 Refrigerant Pipe and Insulation

- Provide and install pipework and refrigerant to manufacturers' recommendations, with the following minimum specifications: Use hard drawn copper pipe to provide a neat installation in all circumstances.
- Support pipes with Uni-strut mounts and proprietary insulated refrigerant pipe mountings of Aeroflex Pipe Hanger Blocks, or approved equivalent alternative.
- Ensure a minimum 5mm clearance between adjacent pipes.
- Space supports to in accordance with industry best practice, but not less than 1500mm centres for horizontal runs and 2000mm centres for vertical runs.
- Pipe insulation to be a minimum of 25mm Armaflex, or approved equivalent alternative, glued at all joins.

- Cut all wall penetrations neatly and, following installation, ensure they are sealed air and water tight. Maintain insulated building vapour barriers maintained in all circumstances.
- Where possible, conceal external exposed insulated refrigerant pipes with machine-folded, painted galvanised sheet steel pipe covers, securely fixed to the building.
- Conceal straight runs of pipes with machine-folded painted 0.8mm galvanised sheet steel pipe covers. Seal open ends of pipe covers with end covers or expanding foam, to prevent rodent entry. Where pipe covers are not possible, wrap pipe insulation with robust canvas reinforced tape and paint with UV resistant paint. Insulate suction and liquid lines as appropriate to the location of the expansion valve and for the need to preserve sub-cooling.

C.5.7 Condensate Pipes and Insulation

- Use PVC or copper condensate pipes. Trap all drains. . Drains to be a minimum of 25mm diameter for systems below 10kW total cooling capacity, and 32mm diameter for systems above 10kW total cooling.
- Provide insulation as per Refrigerant Pipe Insulation above, however only take it to the point of discharge from the building. Note: insulate the condensate drain if it is installed within an external wall cavity. Configure traps to provide a water seal, taking into account the plenum pressure, whether positive or negative. Raise the fan coil unit where necessary to ensure the trap can be accommodated.

C.5.8 Ventilation Fans

- Simplify the design of the mechanical ventilation system where possible to reduce the cost of maintenance and breakdowns.
- Unless otherwise specified by a Department, toilet exhaust systems to be single motor types, commonly used twin fan units such as the Fantech TILE series or dual motor APB series, or approved equivalent alternative.
- Fully insulate flexible connections and fans in high dew point void spaces with two layers of 12mm Armaflex, or approved equivalent alternative. Stagger joints in alternate layers.

C.5.9 Air Conditioning Ducts

C.5.9.1 General

- Regardless of the provision and location of an insulated building vapour barrier, internally insulate all air conditioning ducts (including outdoor air ducts in air conditioned areas) and exhaust ducts from air conditioned areas with perforated, foil-faced insulation to comply with the relevant provisions of the Building Code of Australia. Where the relevant BCA is unknown, provide a minimum 38 mm fibreglass based duct liner.
- Incorporate a vapour barrier on the outside of the duct to minimise the formation of condensation on both the inside and outside of the duct. Seal all joins with mastic to maintain the vapour barrier.
- To prevent cold bridging, install all internal insulation proud of the ends before duct construction. When undertaking on-site installation, ensure that insulation foil facing does not extend to or beyond the duct vapour barrier.

- Where cold bridging to the vapour barrier can not be avoided, provide additional external insulation to prevent the formation of condensation, using two layers of 12mm thick Armaflex, or approved equivalent alternative. Stagger joints in alternate layers. Overlap the internal insulation by a minimum of 100mm.
- Vapour sealing and insulation to comply with section 3-100 Mechanical Services Condensation Control of AIRAH DA20 Humid Tropical Air Conditioning.
- Arrange temperature sensors, fire detectors and other duct insertion fittings so as to eliminate cold bridging and local sweating.

See detail drawings in Appendix A for further information.

C.5.9.2 External Ducts

- Incorporate suitably designed and painted sun screens to external ducts to protect the top of the duct from sun degradation and water erosion.
- Paint the exterior of all external ducts.

C.5.10 Air Diffusion

- Regardless of the provision location of an insulated building vapour barrier, internally insulate all air diffusion serving air conditioned areas or adjoining areas (e.g. toilets to comply with the relevant Building Code of Australia provisions. Where the relevance of the BCA is unknown, provide a 38 mm fibreglass based duct liner.
- Use dropped-face diffusers in climates with a high dew point design temperature
- Use low density timber or polystyrene insulating elements where appropriate to prevent cold bridging of the duct elements to the ceiling void or adjacent air conditioning elements.
- Vapour sealing and insulation to comply with section 3-100 Mechanical Services Condensation Control of AIRAH DA20 Humid Tropical Air Conditioning.

See detail drawings in Appendix A for further information.

C.6 Mechanical Services Contractor Requirements

C.6.1 General

This section details provisions specific to the Northern Region and should be considered as supplementary to other contractual requirements.

C.6.2 Equipment Selections

- Provide detailed equipment schedules to BMW within two weeks of the award of contract or otherwise in accordance with the contractor generated project schedule.
- Where a contractor offers equipment differing from the nominal selection specified by the consultant, the contractor must demonstrate that the offered equipment is equivalent in every applicable aspect. Nominate deviations at the time of tender to allow evaluation. Approval will be at the discretion of the BMW Project Manager in consultation with the Lead Consultant and the Mechanical Consultant.

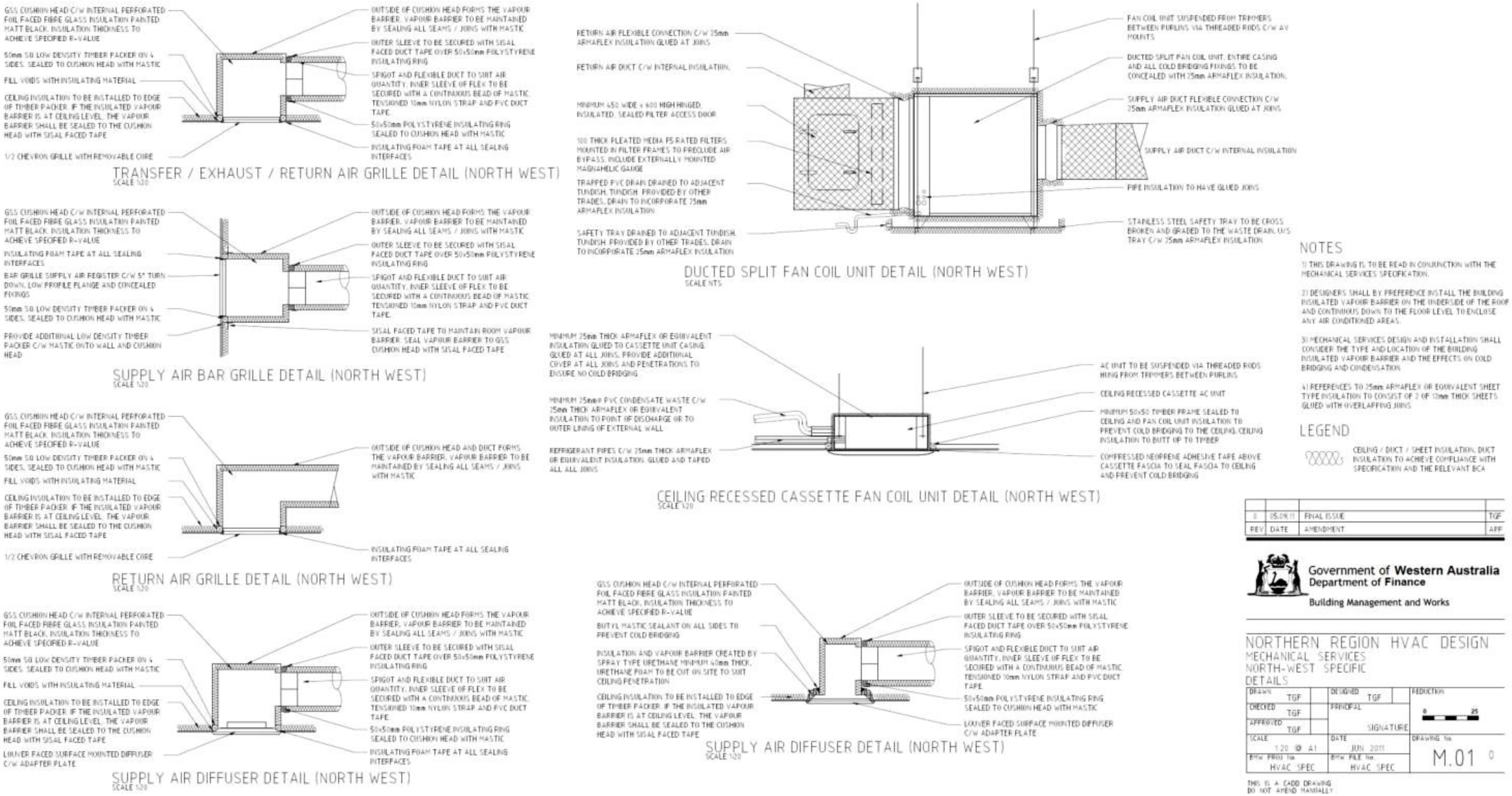
C.6.3 Alternative Equipment

- Notwithstanding this approval, the contractor is responsible for the spatial and services co-ordination for the alternative equipment shop drawings.
- Provide shop drawings for all projects.
- As not all contractors in the Northern Region have the capacity to readily produce AutoCAD based shop drawings and As Constructed drawings, the following dispensation is granted:
    - Manually drawn and scanned (into .pdf format) shop drawings are acceptable for projects where the estimated mechanical cost is less than $20,000 + GST. This is at the discretion of the consulting engineer.
    - Full BMW compliant shop drawings are required for all projects where the estimated mechanical cost is above $20,000 + GST.
- Provide design drawings to the mechanical services contractor in AutoCAD .dwg format for use in constructing the shop and As Constructed drawings. The mechanical services contractor is responsible for the dimensional accuracy of the shop and As Constructed drawings

C.6.4 As Constructed Drawings

- Provide As Constructed drawings for all projects.
- Manually drawn and scanned (into .pdf format) As Constructed drawings are acceptable for projects where the estimated mechanical is less than$20,000 + GST. This is at the discretion of the consulting engineer.
- Provide full BMW compliant As Constructed drawings for all projects with an estimated mechanical cost above $20,000 + GST.
- Provide design drawings to the mechanical services contractor in AutoCAD .dwg format for use in constructing the shop and As-constructed drawings. The mechanical services contractor is responsible for the dimensional accuracy of the shop and “as constructed” drawings.

C.6.5 Standard HVAC details for the North West



C.7 Vapour barrier installation

C.7.1 Purpose

The vapour barrier (wrap) provides a continuous, air tight layer covering the entire building.

C.7.2 Barrier Selection

Materials options:

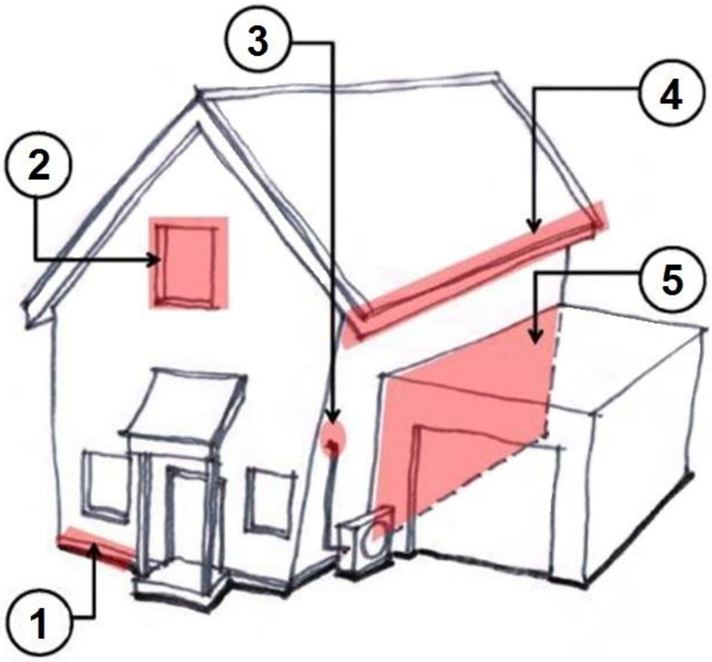
- Option 1 – Thermal break + vapour barrier
  - Aircell Insulbreak 65, or approved equivalent alternative
  - Aircell Insulbreak 80, or approved equivalent alternative
  - Tape – Kingspan aircell insulation tape, or approved equivalent alternative
- Option 2 – Insulating vapour barrier
  - Bradford Medium Duty Thermofoil (730), or approved equivalent alternative
  - Tape – Bradford Enviroseal Proctorwrap SLS, or approved equivalent alternative

C.7.3 Location

The vapour barrier is required at the interface between all conditioned areas and outdoor air, including:

- All external walls
- Suspended floors, where a floor has an undercroft exposed to outdoor air
- Concrete floor slabs on ground should be laid over a continuous DPM – this will act as a vapour barrier
- Some internal walls and ceilings to separate conditioned from non-conditioned spaces
- All roof areas except:
  - Walkways
  - Eaves overhangs
  - Verandas
  - Roof lights
  - Vents and openings.

Figure 19 identifies areas where installation detailing is critical.



1. Wall-to-slab junction
2. Window/door frame installation
3. Service penetration
4. Roof to wall junction
5. Separation of conditioned and non-conditioned spaces

Figure 19 Critical installation details for vapour barriers

C.7.4 Installation

- Provide vapour barrier behind all roof cladding. Extend to join with, and seal to, the vapour barrier installed under the wall cladding to provide a continuous sealed envelope. See *Figures 20 – 23*.
- Run wall vapour barrier horizontally to the outer face of external stud walls from the bottom plate up, over the flashing and extend to join with, and seal to, the vapour barrier installed under the roofing to provide a continuous sealed envelope. See Figure 24.
- Where required, install vapour barrier to internal walls and ceilings under the lining material and seal to perimeter framing and penetrations as for an external wall. See Figure 25.
- Install after fitting of bulk insulation, immediately under the roofing.
- Provide an air gap of at least 40mm between the sarking and the underside of the roof sheeting.
- Horizontal laps: to be at least 150 mm wide, with the direction of the lap ensuring that any water penetrating the wall/roof cladding is shed to the outer face of the membrane.
- End or vertical laps: form laps over framing. Lap joint at least 150 mm wide.
- Seal all joints with pressure sensitive adhesive tape. Use only CSR Reinforced Foil Tape, Bradford 493, or approved equivalent alternative. Support the sheet junctions while tape is being applied and avoid stretching the tape or displacing the membrane. Re-tape any joints that are uneven or creased.
- Fix wall wrap to all perimeter framing members after being pulled taught over the framing in accordance with the manufacturer's written recommendations.
- Run the wrap over openings and leave covered until flashings, thru-fittings, windows, equipment etc are to be installed. Cut the membrane to allow installation of the fitting leaving sufficient margin to allow the vapour barrier to dress onto, and be tape sealed against, the fitting. For mechanical services, penetrations through the roof allow the vapour barrier to be dressed onto, and sealed to, the upstand prior to installation of the mechanical services unit. See *Figures 26 – 28*.
- Where structural members such as rafters pass through the wrap, cut the membrane neatly around the member and seal to the member using pressure sensitive tape.
- Seal all junctions with the structure or penetrations with pressure sensitive tape.
- Participate in pressure testing the building vapour seal as specified.
- Any disruption to the continuity of vapour barrier including but not limited to rips, tears, displacement of the membrane or adhesive tape, is to be made good to ensure that the continuity of the seal is maintained. Gaps in the barrier can be identified by daylight leaking through, and reflecting on, the barrier material. See *Figures 29 – 31*.

Figure 20 Provide vapour barrier behind all roof cladding.

Figure 21 The continuity of the vapour barrier between the wall and the roof must be maintained

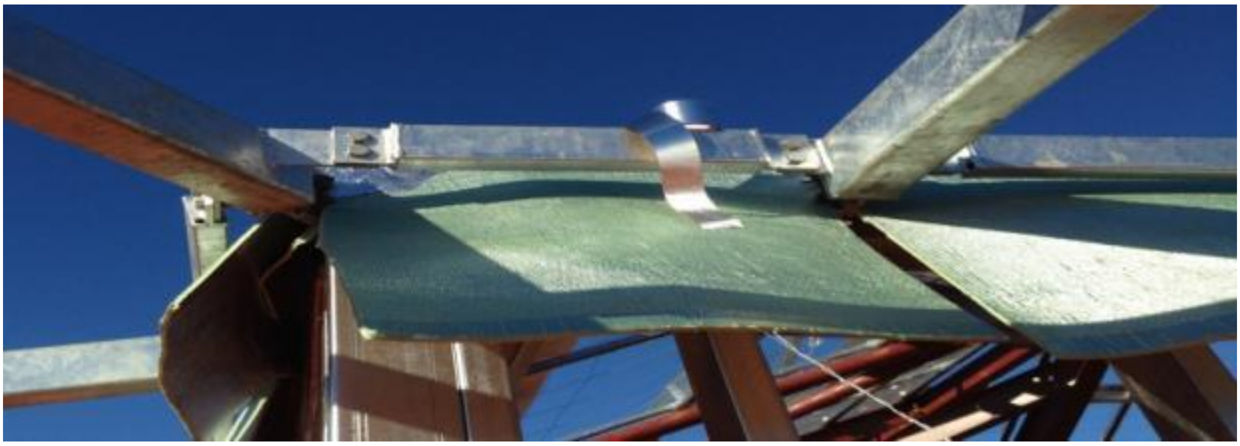


Figure 22 Exercise care to dress barrier down from the roof to the wall

Figure 23 Seal the barrier to any elements that pass through it

Figure 24 Wall vapour barrier should extend from bottom plate to join with the roof vapour barrier to provide a continuous seal

Figure 25 Install a vapour barrier to internal walls to separate conditioned from non-conditioned spaces. Vapour barrier to be located on non-conditioned side of the wall.

Figure 26 Provide a margin around window penetrations to allow vapour barrier to be sealed against it

Figure 27 Group multiple service lines and treat as a single penetration. Use adhesive tape to seal services to the vapour barrier and expanding foam to fill gaps on the inside face of the penetration.

Figure 30 ABOVE AND LEFT: Seal individual service penetrations to both the inside and outside of the vapour barrier using adhesive tape

Figure 29 To increase the tightness of the vapour barrier, seal inside of bottom plate to floor before installing wall linings

Figure 28 Seal hard-to-reach gaps in the barrier with expanding foam filler e.g. at corners where multiple frame members limit access. Gaps in the barrier can be identified by daylight leaking through, and reflecting on, the barrier material.

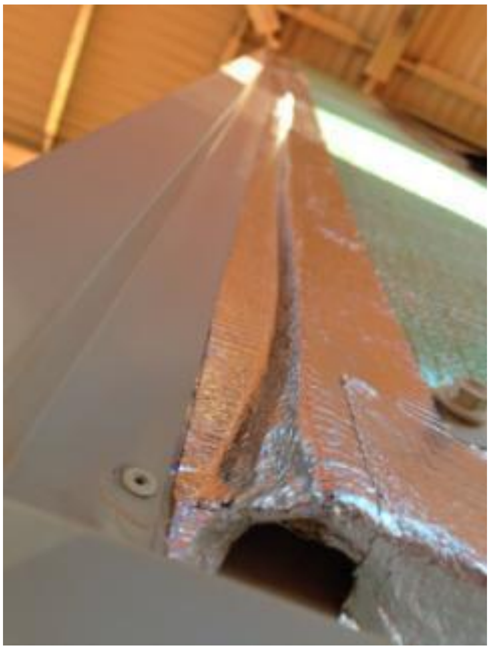


Figure 31 Carefully inspect the barrier to find points of weakness such as ends of flashings where the continuity of the seal is broken. Seal any breaks found, where possible, with adhesive tape or expanding foam as appropriate.

C.7.5 Building vapour seal - pressure test

Achieving a properly sealed building is a key strategy for reducing the risk of condensation in the building and improving the performance of the air conditioning systems. To achieve a properly sealed building attention must be given to the proper installation and sealing of:

- The vapour seal
- External windows and doors
- Roofing, roof penetrations and flashings
- Mechanical services.

The contractor is required to demonstrate, by pressure testing the building before cladding is installed, that work practices on site will achieve a satisfactorily sealed building.

The purpose of the testing is to identify points of weakness in the vapour seal which need to be rectified.

The test must be undertaken after completion of the vapour seal, roof insulation, roofing, skylights, windows, doors, plumbing and mechanical services first fix, but before the majority of the ceiling and walls are installed. This allows inspection of vapour seal joints, junction points and penetrations.

C.7.5.1 How to conduct a building pressure test

- Temporarily seal all normal building gaps/openings, including gaps around doors, window frames, seal exhaust grilles, charge floor wastes/toilets etc.
- Mount a single phase, speed-controllable fan capable of approximately 1500 litres per second in a marine ply panel and fit it securely to a window or door frame. See *Figure 32*.
- Start by running the fan at low speed and increase the fan speed until the pressure inside the building is 10 Pa above the outside pressure. See *Figure 33*.
- Measure the airflow with a certified hood installed over the fan inlet.

- Measure the inside/outside pressure difference at two locations on opposite sides of the building. The target air flow is 500 l/sec at 10 Pa. This target may be adjusted by the designer.
- Initial testing may require higher air flows until breaches in the vapour barrier have been located and sealed.
- Find and seal any openings discovered in the vapour barrier.
- Maintain the pressure differential of 10 Pa for at least 30 minutes.

Figure 32 Increase fan speed until the pressure inside the building is 10 Pa above the outside pressure and measure the air flow from the fan using a certified hood.

Figure 33 Fit pressurisation fan into a doorway and install pressure-sensing meter to read inside and outside air pressures.

C.8 Inspection regimes

In the past, the technical requirements of specifications have generally not been enforced. These requirements must be enforced in their entirety.

There must be a meticulous approach - by all involved in the building - to detailing, manufacture, installation and maintenance of air conditioning systems and the vapour barrier.

No matter how robust a building's design, it is the contractor's responsibility to follow the specification requirements to ensure that construction is carried out to the highest possible standard.

C.8.1 Specification obligations

The specification contains obligations in the following subject areas that **MUST BE** drawn to the attention of the contractor and the relevant subcontractors, and enforced under the contract:

1. Shop detailing and submissions:
   - Detailer qualifications
   - Submission requirements including equipment selections and engineering calculations
   - Timely delivery of completed shop drawings
2. Check Engineer qualifications
3. Commissioning:
   - Staff qualifications
   - Commissioning requirements
4. Inspections and samples:
   - Factory inspection of equipment or a typical sample before installation
5. Compliance:
   - Compliance with all manufacture and installation provisions in the 2012 versions of AS 1668.2 and AS 4254 parts 1 and 2 is mandatory and will be checked.
   - Strict compliance with corrosion protection requirements of the specification
   - North West-specific detailing and installation of A/C and ventilation systems is mandatory and will be checked
6. Vapour barrier:
   - Application of vapour sealing and insulation requirements of the AIRAH DA20 Application Manual
   - Co-ordination between head-contractor and sub-contractors will be required to achieve 100 per cent integrity of the insulated vapour barrier encapsulating each air conditioned building. Pressure testing requirements will be enforced and rectification of any defects required. Any unsealed penetrations through the vapour barrier must be dismantled and reinstalled to seal the openings.
   - Application of pressure testing to confirm performance of vapour barrier installation.
7. The superintendent's representative will inspect every element of the building to verify compliance with the specification.

APPENDIX A – GLOSSARY OF TERMS

AIRAH Australian Institute of Refrigeration Air Conditioning and Heating.

Ambient (Temperature and/or Humidity) – current surrounding conditions – generally applied to conditions prior to any cooling or de-humidification.

Cold bridging or Tracking A situation where building elements provide a ready path for the transfer of heat from an un-cooled space to and air conditioned space. This is manifested in the cooling of the surfaces exposed to the uncooled space.

BMW Building Management and Works – a division of the Department of Finance, Government of Western Australia.

Dew Point The temperature at which water will begin to condense out of the air. Dew point is associated with relative humidity. A relative humidity of 100% indicates the dew point is equal to the current air temperature and that the air is fully saturated with water. When the moisture content remains constant and temperature increases, relative humidity decreases as warmer air can hold more moisture.

Department The tenant/client/occupant. For example Department of Education, Department of Child Protection

DoF Department of Finance

HVAC Heating Ventilating Air Conditioning

Insulating Vapour Barrier A vapour barrier that also provides some thermal insulation so it also acts as a thermal break.

Interstitial condensation Condensation that occurs in spaces not normally visible e.g. within a wall cavity or in the middle of an insulation layer.

Northern Region In this document this refers to the Kimberley and Pilbara Regions north of the 23rd parallel and within the jurisdiction of BMW Northern Region.

Relative humidity A measure of water vapour present in air measured against the air's ability to hold vapour – usually expressed as a percentage.

Set temperature The temperature which the air conditioner is working to achieve, and once reached the air conditioner cooling cycle will shut down until the temperature rises again.

Vapour Barrier A material that retards/impedes the migration of water vapour.

Water vapour Water in a gaseous state present in air.

APPENDIX B – REFERENCED DOCUMENTS

Building Code of Australia (BCA)
Legislated building code that references Australian Standards

Australian Standard AS 1668.2
The Use of Ventilation and Air Conditioning in Buildings

Australian Standard AS 1668.2
The Use of Ventilation and Air Condition in Buildings

Australian Standard AS 4254
Ductwork for Air-handling Systems in Buildings

Australian Standard AS 3666.1 and .2 and .3
Air-handling and Water Systems in Buildings

Australian Standard AS 2107
Acoustics – Recommended Design Sound Levels and Reverberation Times for Building Interiors

Australian Standard AS 1851
Maintenance of Fire Protection Systems and Equipment

AIRAH Application Manual DA20
Humid Tropical Air Conditioning

AIRAH Application Manual DA9
Air Conditioning Load Estimation and Psychrometrics

Air Conditioning Issues in Humid Areas
BMW, Building Research and Technical Services, 2011

Maintenance Minimisation Manual
BMW, Building Research and Technical Services

Condensation in Buildings: Information handbook
Australian Building Codes Board, 2011

Opportunities and Consequences of Condensation
Dr Richard Aynsley, F.AIRAH, F.AIA, 2010

HL258 Moisture: Build to Keep It Out of Homes in Warm, Humid Climates
Clemson University Cooperative Extension Service, 1998

Study Report No.60 – An Anatomy of Mildew Risk with Reflective Foil Insulation
BRANZ H A Trethowen, 1995

Moisture Movement In Walls In a Warm Humid Climate
A Tenwolde and H T Mei, 1986