Selecting a Cooling System for Acute Health and Aged Care Facilities

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Department of Human Services
Public Health Division

Feedback
The Department welcomes feedback on this document. Comments can be made in writing to the *Legionella* Risk Management Project within the Public Health Division, or via e-mail to lrmp@dhs.vic.gov.au

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Executive Summary

The Department of Human Services and funded agencies rely on engineering systems to provide a safe working environment for service delivery. Cooling systems are used in Victorian public hospitals, and other aged and health care facilities to provide a comfortable environment for staff and patients.

Water cooling towers associated with many cooling systems provide a favourable environment for *Legionella* bacteria growth and a mechanism for transmission of *Legionella* bacteria into the atmosphere, via the discharge of aerosols in cooling tower exhaust. To reduce the impact of Legionnaires' disease on the community, the Victorian Government has established a risk management strategy which strengthens the regulatory framework and improves maintenance standards for all new and existing water cooling towers in Victoria.

Hospitals, aged and health care facilities with water cooling tower systems have been identified as the highest risk premises for potential outbreaks of Legionnaires' disease. This is largely due to the vulnerability of patients in these premises. These sites therefore require the most comprehensive risk management strategies including risk assessments, maintenance and bacterial testing.

To complement this risk management strategy, the Department of Human Services has prepared this Guideline to assist when selecting a cooling system. It is intended for new projects or major redevelopment when new cooling systems are being designed, or existing systems being refurbished. The Guideline sets out key parameters, describes alternative basic systems, selection methodology and key considerations for use by Departmental and public bodies such as hospitals. All new cooling towers must comply with the requirements of the Australian/New Zealand Standard AS/NZ 3666.

Generic studies, using life cycle costing, were carried out to determine the conditions under which air cooled systems would perform more favourably than water cooled systems.

The Guide clearly leans towards the use of air cooled rather than water cooled systems, except where there are engineering or physical constraints in the development of new facilities. Refurbishment may need to be dealt with on a site-specific basis, as other engineering, site and cost considerations apply in these circumstances.

The setting of the performance requirement for air conditioning and the cooling load has the most obvious impact on the design of a cooling system. Good design and demand management can reduce the size of the cooling load.

Where the design of a cooling system is part of a redevelopment process, consideration will have to be given to upgrading associated engineering infrastructure such as power supply, monitoring and control systems.

1 Introduction

This publication outlines essential considerations when selecting the right cooling system for an aged care or acute health setting:

- Description of cooling systems and equipment available.
- Key issues associated with cooling systems.
- Design and demand management.
- A system selection methodology.
- Factors to consider in evaluating options.

1.1 Target Audience

This document is intended for use primarily by Department of Human Services, hospital and other public aged and health care representatives involved in capital works, engineering infrastructure and facilities management. Other users will include Project Control Groups (PCG), hospital and agency staff, facility managers, project managers, consultants and contractors engaged to design, deliver and install capital works projects.

Best use of this guideline can be made during the early planning stages of infrastructure development or refurbishment projects, as well as in the feasibility study/schematic design phase, when alternative cooling systems are considered and proposed for a capital works project.

1.2 Purpose of this Guideline

This Guideline provides a process for systematic selection, design, and implementation of cooling systems, by considering the true life cycle costs associated with various options (including *Legionella* risks associated with water-based cooling tower systems).

Applying conventional life cycle costing methods to choose a cooling system assumes that the least cost option meeting the functional requirements of the project will be identified.

Full compliance with relevant standards, statutory regulations and codes of practice is also assumed.

Air-based systems are not suitable for all situations. Where existing water cooled systems are operating efficiently and safely, they should be allowed to remain in service. Risk Management Plans must be prepared and implemented, with a program of annual reviews and audits for all existing cooling towers remaining in service.

For assistance in preparing Risk Management Plans for cooling tower systems, see these documents published by the Department's Public Health Division:

- *A Guide to Developing Risk Management Plans for Cooling Tower Systems*
- *Managing the Risk of Legionnaires' Disease—Supplementary Notes for Hospitals*
- Other resource documents located on the Internet at www.legionella.vic.gov.au

2 Cooling System Functions

Cooling systems provide space cooling (such as air conditioning) or process cooling. In specialised applications, cooling systems meet process requirements such as computer room environmental control or medical imaging systems.

2.1 Space Cooling

In space cooling, pre-treated cool air is distributed into the air conditioned space via the supply system, usually air ducts or plenums.

Temperatures rise through the heat gains within each room:

- Body heat emitted by occupants.
- Warm air introduced from outside.
- Heat generated by lights and other electrical and mechanical equipment.
- Solar heat gain through windows.
- Heat gain through the building fabric and abutting non-air conditioned space.

Heat is transferred from the room to the outside atmosphere in a four-stage **heat transfer process:**

- **Stage 1**—Heat is **removed** from the conditioned space by extracting the room air.
- **Stage 2**—Heat is **exchanged** from the extracted warm room air by passing the air over a coolant circulating in the cooling coil inside an air conditioning system.
- **Stage 3**—Heat is **extracted** from the coolant by refrigerant compression and evaporation in the chiller and transferred to the condenser of the chiller.
- **Stage 4**—Heat is normally **rejected** to the atmosphere from the condenser via a cooling tower (water cooled) or via fan-forced ambient air passing through the condenser (air cooled).

Air and water based cooling systems use identical processes during Stages 1, 2 and 3. The heat rejection equipment used in Stage 4 of the heat transfer process is different in each.

2.2 Process Cooling

To maintain proper functioning of process equipment or systems, the waste heat emitted must be removed.

The heat transfer process is similar to that described for the space cooling, except that Stages 1 and 2 are normally combined. Stage 3 and 4 are the same as for space cooling.

2 Cooling System Functions

Figure 1: Cooling Systems and Their Uses

Cooling System	Comment
Room air conditioners	Capacity range of 0 to 10 kW per unit. Suitable for an area smaller than 100 m^2.
Evaporative cooling system	Generally used in areas where a large quantity of air is exhausted. For example in kitchens and factories.
Packaged unit with integral air cooled condenser	Capacity range of 10 to 120kW. Suitable for a maximum area of 100 to 1200 m^2 per unit.
Split system with outdoor air cooled condenser	Capacity range of 10 to120kW. Suitable for an area of 100 to 1200 m^2 per unit.
Chilled water system (air cooled or water cooled chillers)	Capacity range of 120 to 5000kW. Suitable for an area of 1200 to 50000 m^2 per chiller. Cooling towers are required for water cooled chillers.
Geothermal cooling system	Deploys the earth's constant temperature of 15°C to 17°C at depths of between 50 and 100 metres as a heat sink. Refrigeration equipment and associated heat rejection devices are not used.

3 Typical Hospital Cooling Systems

Three main components are commonly found in hospital cooling systems:

- **Air conditioning sub-systems**—Local heat exchanger.
- **Chillers**—Energy-driven heat exchanger between heat rejection equipment and internal air conditioning sub-systems.
- **Heat Rejection Equipment**—Exchanges the heat to atmosphere.

3.1 Air Conditioning Sub-Systems

Sub-systems provide heating and cooling to an occupied space by distributing the conditioned air. Induction and fan coil units will have either chilled water or refrigerant piping connected as a means of lowering the ambient air temperature. There are several types of sub-systems:

- Single-zone ducted air system (constant volume)
- Multi-zone ducted air system (constant volume)
- Variable air volume system
- Induction units
- Fan coil units.

The choice of sub-system is unrelated to the selection of air cooled or water cooled systems.

3.2 Chillers

The following types of water cooled chillers are currently readily available, each with a corresponding capacity:

Scroll	120–250 kW
Screw	250–1200 kW
Reciprocating	150–1500 kW
Centrifugal	1500–4000 kW
Absorption	1500–5000 kW.

Most are also available in an air cooled form, with the maximum capacity currently available approximately 1500 kW.

When selecting a chiller, consider:

- **Fuel source**—Absorption chillers can be powered by steam, gas or high temperature hot water for small capacity units. All other chillers are powered by electric motors. Gas engine-driven reciprocating chillers are available, but not widely used in Australia
- **Operating cost**—Running costs for the scroll, screw and reciprocating chillers are similar. The running cost for the centrifugal type is 40 to 50 per cent lower than the others. Differential maintenance costs need to be factored in with regard to both options. For water cooled systems this must include the costs associated with compliance with the Health *(Legionella)* Regulations 2001 for water cooled systems.
- **Flexibility**—Scroll, screw and reciprocating chillers operate satisfactorily on low load conditions that are well below their rated capacity. Centrifugal chillers operate satisfactorily down to 20 to 35 per cent of their rated capacity.

3 Typical Hospital Cooling Systems

- **Expected life**—If properly maintained, electric chillers should last more than 20 years and absorption chillers over 30 years.
- **Energy efficiency**—Facilities that make use of stored energy (such as ice storage) are useful for situations where cheap off-peak electricity is available. Absorption chillers are a viable option where there is excess heat available (such as co-generation plants).

3.3 Heat Rejection Equipment

In the final stage of the heat transfer process, the removed heat needs to be rejected into the atmosphere, lake or a similar form of heat sink, via an appropriate and effective heat exchange medium. Heat rejection into the atmosphere is the most widely used method.

The most common types of heat rejection equipment are:

- Cooling towers
- Evaporative condensers
- Air cooled condensers.

3.4 Cooling Towers and Evaporative Condensers

Cooling towers lower the temperature of recirculated condenser water, by bringing the water into contact with fan-forced or induced atmospheric air. Cooling towers provide an ideal environment for the growth of *Legionella* bacteria, because of the temperature of circulating water in the tower and the presence of nutrients.

Victorian legislation requires registration of all cooling tower systems and the staged development, implementation and annual auditing of Risk Management Plans to minimise the possibility of *Legionella* contaminated aerosols being discharged into the atmosphere from the cooling tower.

Evaporative condensers operate in a similar way to cooling towers and are deemed to be cooling towers under the Building *(Legionella)* Act 2000.

3.5 Air Cooled Condensers

In an air cooled condenser, heat is transferred from the refrigerant in the condenser coil to the cooler ambient air. Atmospheric air is fan-forced to pass through the condenser coil and effect the required heat transfer.

An air cooled condenser could be linked with a packaged air conditioner, chiller, or be a stand-alone unit.

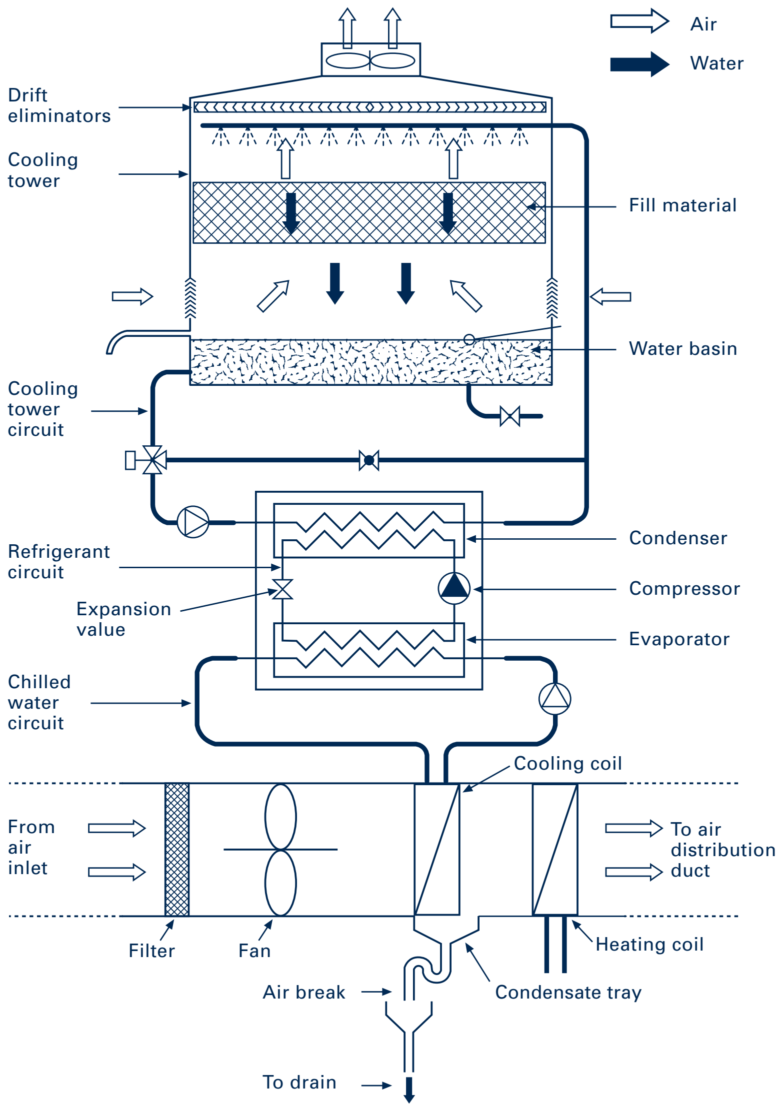
Thermal efficiency is lower than for cooling towers. As a result:

- Area or footprint required for accommodating air cooled condensers is higher than cooling towers.
- Operating costs of air cooled condensers are generally higher.

There are also limitations on the distance separation and installation height differential between the chiller and the condensers. Condensers should not be more than 40 to 50 metres above or below and not more than 80 metres away from the chiller.

An air cooled condenser has one significant advantage, however. Because there is no recirculating water in an air cooled condenser, the public health risk of *Legionella* is eliminated. Consequently, there are no associated costs for compliance with *Legionella* regulations.

Figure 2: Typical Cooling Tower System Used in an Air Conditioning System



4 Design Issues

The design of facilities can have a big impact on cooling loads and systems selected. Where possible, the initial design should be examined and modified to ensure the measures noted below are all considered.

This may apply more directly to new projects than to redevelopment or refurbishment. However, passive energy design can be undertaken at little cost to the agency, while substantially reducing plant/reticulation costs and achieving recurrent savings.

4.1 Design and Demand Management

A key preliminary requirement in selecting a cooling system is an estimation of the project's kilowatt capacity requirements, including potential future load growth demands.

Air conditioning requirements can be minimised from the outset through:

- Passive design techniques such as building mass, correct solar orientation and planning for effective ventilation, insulation and material selection.
- Separating zones that need strict air temperature control and minimal noise, such as hospital operating theatres or intensive care units, from general use areas where a much wider range of temperatures and greater noise levels are acceptable—for example areas such as administration, stores, cafeteria, records and reception.
- Performance targets for temperature can be reviewed and where appropriate, this range widened. Less stringent engineering demands reduce emphasis on cooling system use and outputs.

Refer to existing material describing the critical aspects for hospital operating theatres, as set out in the DHS *Capital Development Guideline 6.3 Air Conditioning in Health Care Buildings.* This should be used to define system design parameters such as temperature ranges, amounts of fresh air and air volume changes.

For other purposes, use performance characteristics set by the agency in consultation with the Department of Human Services. Also consider industry norms, finances and as a rule of thumb, meeting normal expected loads for 95 per cent of predictable meteorological conditions.

4.2 Strategies to Reduce Plant Size

These design activities can contribute to a reduction in both plant size and costs for both capital and recurrent expenses. Good design strategies include:

- Careful solar orientation of building.
- Providing external shading to reduce solar gain.
- Designing for microclimatic and prevailing wind conditions.
- Carefully selected construction materials to provide effective cladding, ceiling and wall insulation.
- Encouraging use of natural ventilation.
- Reducing infiltration and providing air locks where needed.
- Reviewing window size and location.
- Using more efficient lighting systems and energy efficient equipment/appliances
- Installing exhaust systems for high heat generating equipment
- Participating in energy efficient design and rating systems.

5 Selection Methodology

To determine which type of cooling system should be deployed for a new project, first identify the area to be temperature-controlled and the limits to be maintained.[1]

The following assessment tasks should then be carried out[2]:

- Determine **functional and operational requirements** by assessing the cooling load and load profiles taking into consideration the location, hours of operations, number/types of occupants and equipment being used.
- Determine the **required system configuration** in terms of number and plant capacity, by taking into account total capacity, essential loads, operational requirements, reliability and maintenance considerations.
- Identify **planning and environmental issues,** in particular those that would prohibit the use of certain types of equipment, or require costly measures to render the proposed equipment fit for use.
- For redevelopment projects, **assess retention of existing plant** and compare with replacement costs.
- Review of **available energy alternatives,** including waste heat from industrial processes.
- Identify **alternative types of systems** and equipment that may be suitable.
- Identify **all associated works** required including power supply and construction.
- Carry out a **life cycle cost analysis** to identify the least cost option, considering capital cost, recurrent costs for operation, maintenance and repairs over the same time frame (say 20 to 25 years).
- Review the risk profile using the **risk rating tool**[3] and give due consideration to systems that represent minimal risk. The comparative cost penalty should be identified in terms of different cooling systems, as well as overall asset operations and maintenance budget.
- If a water cooled system is identified as the least cost option but the air cooled system remains as a viable alternative, consider **whether the associated risks should be eliminated** by paying a cost premium to go with the air cooled system.

1 See the Department's *Air Conditioning Capital Development Guidelines, 6.3 Air Conditioning in Health Care Buildings.*
2 The methodology set out below is best used for a new facility. With redevelopment/refurbishment, integration of the existing system needs separate attention.
3 Refer to *Managing the Risk of Legionnaires Disease—Supplementary Notes for Hospitals.*

6 Key Selection Factors

The following will help to determine the size and number of chillers required for a cooling system. This in turn influences the selection of a cooling system, via the life cycle cost analysis.

6.1 Cooling Load Profiling

The cooling load includes peak and future loads. In particular, consider the following:

- **Peak load demand**—Determines the overall capacity of the system.
- **Part-load requirements**—Determines the number and size of chillers required. With high capacity centrifugal chillers, part-load application should not be less than 20 to 35 per cent of the full load capacity. If the part-load requirement is less than this amount, a smaller capacity chiller should be selected.
- **Essential services requirements**—Determines system reliability requirements
- **Future load requirements**—This may alter the cooling load sufficiently to alter a decision on the choice of components or cooling system

6.2 N+1 Strategy

Chillers and associated cooling towers need to be shut down regularly for routine maintenance and cleaning. For a critical continuous process that cannot afford service disruptions, a single unit will not be adequate.

Providing a back-up unit is known as the 'N+1 strategy'. For example, if the total capacity requirement is 1500 kW, two units each of 750 kW should be provided instead of one unit of 1500 kW, so long as the essential load is less than half the total load. Otherwise, two units each with a capacity equal to the essential load are required.

6.3 Operational Regimes

Determine which portion of the total load is required for 24-hour operation. It is more cost efficient to operate a smaller capacity chiller at full load, than a bigger capacity chiller at partial load.

6.4 Energy Efficiency

The government has recently announced a policy to pursue 15% energy savings over the next 5 years from 2001 in public hospitals. In order to meet this objective the available energy sources and relative energy costs will need to be considered. If conventional energy sources are not readily available and high infrastructure cost would be incurred in bringing the energy source to the development site, then alternative renewable energy sources (such as geothermal) should be considered. A life cycle costing analysis can help determine the viability of the proposed alternative.

If the price differential between electricity and natural gas is high, gas-fired reciprocating chillers or absorption chillers should be considered.

6.5 Climatic Conditions

Humid conditions favour the selection of air cooled chillers.

6.6 Siting

Environmental planning constraints on proposed plant location must be considered. The need to minimise noise emission in residential areas outside office hours by introducing sound attenuation would increase the cost of an air cooled system.

Cooling towers must be sited at least six metres away from any fresh air intake points. There are situations where this minimum separation distance cannot be achieved. In this case, air cooled systems must be selected.

New water-based cooling towers should not be located in the immediate vicinity of dedicated aged care residences or other acute health care facilities, where 'at risk' patients are constantly present and potentially exposed to airborne *Legionella* bacteria from cooling tower exhausts.

6.7 Accessibility

For ease of maintenance, the cooling tower system needs to be:

- Readily accessible, taking into account occupational health and safety factors.
- Easily monitored in terms of testing, servicing, cleaning, and inspection.

6.8 Life Cycle Cost Considerations

Comparative net present values of life cycle costs over a period of 20 years for various plant capacities will help to test proposed options. Use the following to calculate the life cycle cost of each option:

- **Capital costs**—Includes the total cost of installation together with building cost, associated electrical power supply reticulation and control costs.
- **Energy costs**—The future costs of energy associated with all options and may require consideration of a range of tariff options.
- **Programmed maintenance and servicing costs**—Total costs for a water cooled system include routine water testing and treatment costs, at a frequency determined by the Risk Management Plan.
- **Risk management costs**—For the water cooled system, this is the cost of developing, implementing and auditing the Risk Management Plan, as prescribed by Health *(Legionella)* Regulations 2001.

6.9 Physical Attributes

A water-based cooling tower takes up about 25 per cent of the area needed by an air cooled system using a 'condenser farm' configuration for heat rejection.

7 Air Cooled or Water Cooled Systems?

Ultimately, the selection of a water or air cooling tower system will come down to a choice between factors such as viability, cost and risk. The cost premium versus the risks associated with a particular site will vary. If the risk is too high, then an alternative to the water cooled system is the appropriate selection.

7.1 When Air Cooled Systems Are Best

Air cooled systems are strongly favoured over water cooled systems where there are 'at risk' people accommodated nearby. They are also a good choice when:

- The required system capacity is small.
- The system is not required to operate after office hours and in particular, at night.
- Plant won't be sited in or around noise-restricted zones, such as residential areas.
- There is adequate, accessible rooftop space for the equipment.
- Siting of cooling towers is restricted, due to *Legionella* risk minimisation constraints.
- The climate is tropical. (The effectiveness of water cooled systems is significantly reduced by high humidity.)

7.2 When Water Cooled Systems Are Best

Water cooled systems are generally better than air cooled systems when:

- The required system capacity is large.
- The system needs to operate at night.
- Plant can be sited in or around a low risk area.
- There is not enough space for air cooled equipment.

7.3 Recent Life Cycle Cost Comparisons

Results from recent generic studies on comparative life cycle costs of air cooled and water cooled systems show that each performs better over a certain range of plant capacity. These conclusions are summarised in Figure 3.

Figure 3: Life Cycle Cost Comparisons

Capacity Range (kW)	Area Served (m^2)	Favourable System
150 to 750	1500 to 7500	Air cooled
750 to 1500	7500 to 15000	Water cooled (with small margins)
1500 and above	15000 and above	Water cooled (with increasing margins)

7 Air Cooled or Water Cooled Systems?

Figure 4: Sample Comparative Net Present Values: 1500 kW Capacity

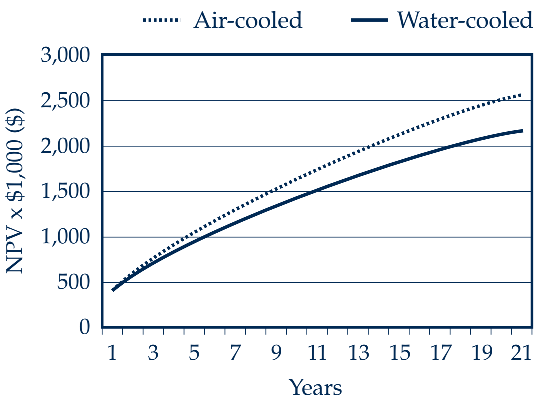


Figure 4 shows a life cycle cost analysis comparing air cooled and water cooled options for a 1500kW capacity requirement.

7.4 Cooling Towers and Risk Management

Acute health and aged care facilities with a residential component are regarded as being of the highest risk for Legionnaires' disease. If a water-based system is selected, the risks must be managed to comply with the Building *(Legionella)* Act 2000 and a stringent maintenance program applied, in accordance with the Health *(Legionella)* Regulations 2001.

A full Risk Management Plan must also be prepared before the cooling tower system is commissioned. The plan is to be audited annually.

7.4.1 Stagnant Water

To address the risk of stagnant water in the cooling tower system, as a minimum:

- Any likelihood of stagnant water being present in the system must be eliminated.
- Piping for the cooling tower system must be installed without any 'dead legs'.
- A circulating pump is to be installed, with a timer fitted to automatically circulate the water at regular intervals.

7.4.2 Nutrient Growth

To address the risk of nutrient growth in the cooling tower system, as a minimum:

- The presence of nutrients for *Legionella* bacteria growth must be minimised, through a comprehensive water treatment program and regular cleaning.
- The cooling tower should be constructed from suitable materials that will not corrode.
- The tower basin and 'top deck' should be protected from sunlight.

7.4.3 Water Quality

To address the risk of water quality in the cooling tower system, as a minimum:

- Water in the system must be treated with appropriate concentrations of biocides. Use of both oxidising and non-oxidising biocides is recommended. Treatments need to be varied in accordance with risks, for example: climatic and seasonal factors, and site conditions, such as dust from construction.
- Water chemistry must be regularly reviewed, maintained and controlled.
- The frequency, process and trends in bacterial testing (Heterotrophic Colony Count and *Legionella)* must be reviewed.
- The cooling tower system must be fitted with an automatic biocide-dosing device and auto-bleed device, to maintain water quality and to control the growth of *Legionella* bacteria introduced into the system.

7.4.4 Cooling Tower System Design

To address the risk of deficiencies in the cooling tower system, as a minimum:

- The cooling tower to be selected must be designed and constructed to comply with the Australian Standard AS 3666. In particular, it must be fitted with effective drift eliminators.

- The cooling tower system must be designed to minimise the number of start-stop operations, by using a variable speed fan and by lowering the shut-down temperature.
- The depth and volume of the tower's water basin must be appropriate for likely drain-off from the piping system when the system is shut down.

In addition, consideration should be made to the ongoing cleaning of the system including potential drainage of the system during the decontamination process.

7.4.5 Location and Access

To address the risk of location and access problems in the cooling tower system, as a minimum:

- Ensure that the cooling tower provides appropriate access for maintenance staff. Siting and access provisions should accommodate occupational health and safety interests.
- Physically separate cooling towers from vulnerable people, with increased maintenance as a contingency arrangement, if required.[4] Communication between engineering, maintenance and clinical staff on-site is essential in reducing patient, worker and visitor risks associated with cooling towers.

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4 For more detail, refer to *Managing the Risks of Legionnaires' Disease—Supplementary Notes for Hospitals* and *Guide to Developing Risk Management Plans for Cooling Tower Systems.*

Attachment 1

Checklist—Project Proposal Review

1. Have the part-load, 24-hour load and essential load all been assessed in determining the system capacity requirements and configuration?

2. Does the proposed system configuration (number of chillers and unit capacity) allow for operational efficiency under part-load, 24-hour load and essential load conditions?

3. Does the proposed system configuration support N+1 strategy for continuity of service to the essential load requirement?

4. Has a life cycle costing analysis been carried out to identify the least cost option?

5. Has the total installed cost (including building cost) been factored into the life cycle costing?

6. Have the programmed maintenance and servicing costs and risk management costs been factored into the life cycle costing?

7. What impact will the proposed system have on energy consumption?

8. What is the cost premium (expressed as a percentage of the project development cost) for elimination of *Legionella* risks by installing an air cooled system?

9. If a water cooled system is identified as the least cost option but the air cooled option remains a viable alternative, should the risk associated with cooling towers be eliminated by paying a cost premium to go with the air cooled option?

Attachment 2

Checklist—Replacing an Existing Water Cooled System

1. Is it time for chiller replacement?
2. Is there sufficient space for air cooled condensers on the roof?
3. Is the existing chiller located too far from cooling towers?
4. Is it technically feasible to replace existing cooling tower with condensers?
5. Is the noise of an air cooled chiller an issue with neighbours and others in close proximity?
6. Has the process for selecting a system satisfied all functional requirements?
7. Has a life cycle costing been undertaken that identifies the least cost option?
8. Is it worth spending a cost premium to eliminate *Legionella* risks?