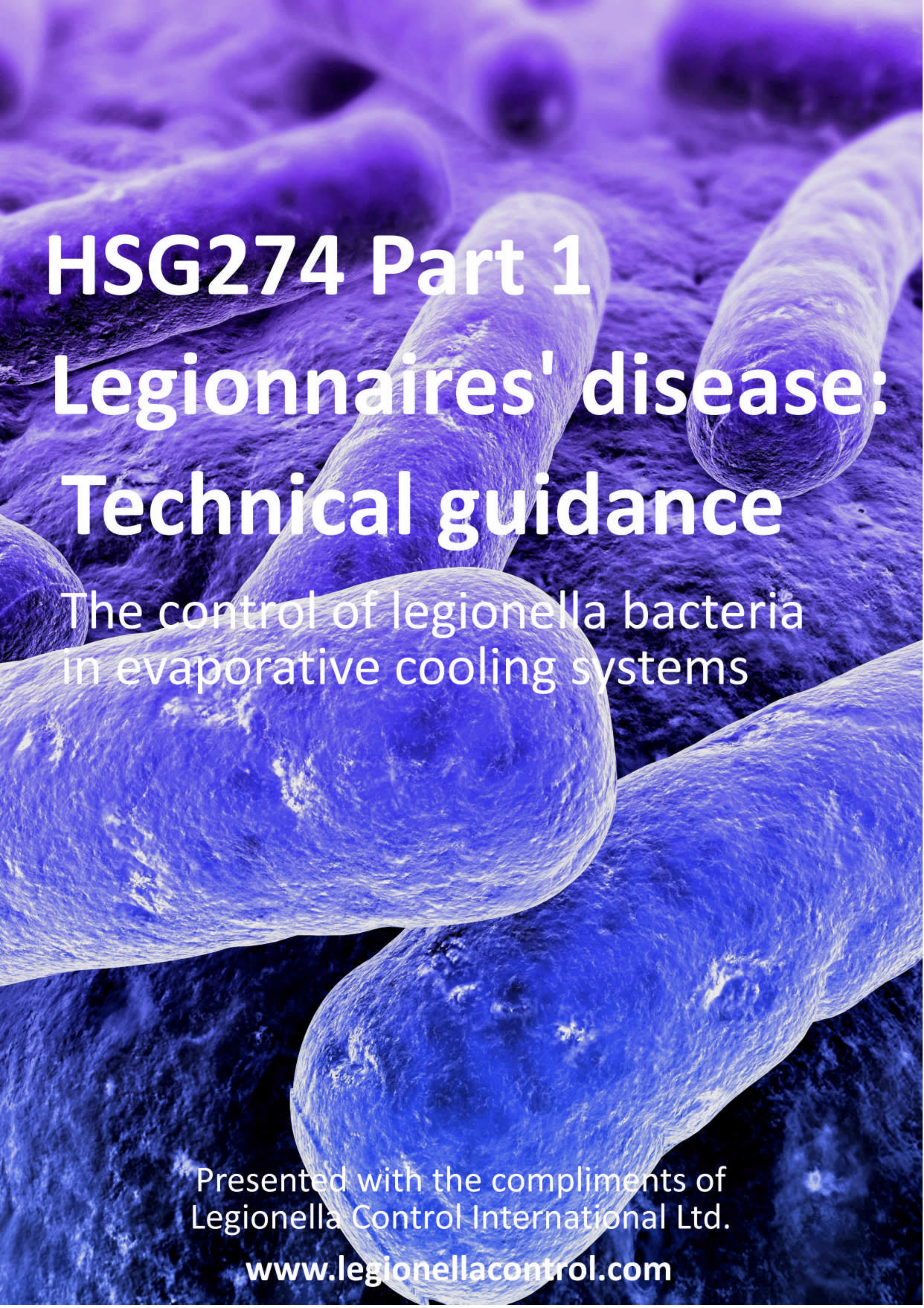

HSG274 Part 1

Legionnaires' disease: Technical guidance

The control of legionella bacteria in evaporative cooling systems

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HSE

Health and Safety Executive

Legionnaires' disease: Technical guidance

Part1: The control of legionella bacteria in evaporative cooling systems

This guidance is for dutyholders, which includes employers, those in control of premises and those with health and safety responsibilities for others, to help them comply with their legal duties. These include identifying and assessing sources of risk, preparing a scheme to prevent or control risk, implementing, managing and monitoring precautions, keeping records of precautions and appointing a manager responsible for others.

The guidance gives practical advice on the legal requirements of the Health and Safety at Work etc Act 1974, the Control of Substances Hazardous to Health Regulations 2002 concerning the risk from exposure to legionella and guidance on compliance with the relevant parts of the Management of Health and Safety at Work Regulations 1999.

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Contents

Introduction

1 This guidance is for dutyholders, which includes employers, those in control of premises and those with health and safety responsibilities for others, to help them comply with their legal duties. It gives practical guidance on how to assess and control the risks due to legionella bacteria.

2 Any water system that has the right environmental conditions could potentially be a source for legionella bacteria growth. There is a reasonably foreseeable legionella risk in your water system if:

- water is stored or re-circulated as part of your system;
- the water temperature in all or some part of the system may be between 20–45 °C;
- there are deposits that can support bacterial growth, such as rust, sludge, scale and organic matter;
- it is possible for water droplets to be produced and, if so, whether they can be dispersed;
- it is likely that any of your employees, contractors, visitors etc could be exposed to any contaminated water droplets.

Health and safety law

3 *Legionnaires' disease: The control of legionella bacteria in water systems. Approved Code of Practice*[1] gives specific information on the health and safety law that applies. In brief, general duties under the Health and Safety at Work etc Act 1974 (the HSW Act)[2] extend to risks from legionella bacteria, which may arise from work activities. The Management of Health and Safety at Work Regulations 1999 provide a broad framework for controlling health and safety at work (see www.hse.gov.uk/risk for more information). More specifically, the Control of Substances Hazardous to Health Regulations 2002 (COSHH)[3] provide a framework of duties designed to assess, prevent or control the risks from hazardous substances, including biological agents such as legionella, and take suitable precautions.

4 The essential elements of COSHH are:

- risk assessment;
- prevention of exposure or substitution with a less hazardous substance if this is possible, or substitute a process or method with a less hazardous one;
- control of exposure where prevention or substitution is not reasonably practicable;
- maintenance, examination and testing of control measures, eg automatic dosing equipment for delivery of biocides and other treatment chemicals;
- provision of information, instruction and training for employees;
- health surveillance of employees (where appropriate, and if there are valid techniques for detecting indications of disease) where exposure may result in an identifiable disease or adverse health effect.

5 Under general health and safety law, dutyholders, including employers or those in control of premises, must ensure the health and safety of their employees or others who may be affected by their undertaking. They must take suitable precautions to prevent or control the risk of exposure to legionella. They also need to either understand, or appoint somebody competent who knows how to identify and assess sources of risk, manage those risks, prevent or control any risks, keep records and carry out any other legal duties they may have.

Other relevant legislation

6 Employers must be aware of other legislation they may need to comply with, which includes the Notification of Cooling Towers and Evaporative Condensers Regulations 1992;[4] Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR);[5] the Safety Representatives and Safety Committees Regulations 1977 and the Health and Safety (Consultation with Employees) Regulations 1996.[6]

Notification of Cooling Towers and Evaporative Condensers Regulations 1992
7 These Regulations require employers to notify the local authority, in writing, if they operate a cooling tower or evaporative condenser and include details about where they are located. The Regulations also require notification when such devices are no longer in use. Notification forms are available from your local environmental health department.

Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR)
8 These Regulations require employers and those in control of premises to report accidents and some diseases that arise out of or in connection with work to HSE. Cases of legionellosis are reportable under RIDDOR if a medical practitioner notifies the employer and the employee's current job involves work on or near cooling systems that are located in the workplace and use water or work on water service systems located in the workplace, which are likely to be a source of contamination. For more information, see HSE guidance at www.hse.gov.uk/riddor/index.htm.

The Safety Representatives and Safety Committees Regulations 1977 and the Health and Safety (Consultation with Employees) Regulations 1996
9 These Regulations require employers to consult trade union safety representatives, other employee representatives, or employees where there are no representatives, about health and safety matters. This includes changes to the work that may affect their health and safety, arrangements for getting competent help, information on the risks and controls, and the planning of health and safety training.

Identify and assess sources of risk

10 Carrying out a legionella risk assessment and ensuring it remains up to date is required under health and safety law and is a key duty when managing the risk of exposure to legionella bacteria. In conducting the assessment, the dutyholder must appoint a competent person or persons, known as the responsible person, to help them meet their health and safety duties, ie take responsibility for managing the control scheme. If the necessary competence, knowledge and expertise does not exist, there may be a need to appoint someone externally (see paragraphs 16–22).

11 The responsible person appointed to take day-to-day responsibility for managing risks in their business will need to understand the water systems, any equipment associated with the system such as pumps, heat exchangers etc, and all its constituent parts. They should be able to identify if the water systems are likely to create a risk from exposure to legionella bacteria by assessing if:

- water is stored or re-circulated in the system;
- the water temperature in all or some parts of the system may be between 20–45 °C;
- there are deposits that support bacterial growth, including legionella, such as rust, sludge, scale, organic matter and biofilms;
- it is possible for water droplets to be produced and, if so, whether they can be dispersed;

- it is likely that any of your employees, contractors, visitors, the public etc could be exposed to contaminated water droplets.

12 The practical risk assessment should include a site survey of all the water systems and consider other health and safety aspects of undertaking such investigations, eg working at height or in confined spaces or the need for permits-to-work when doing this.

13 Appendix 1 provides information on the key requirements when assessing the risks associated with evaporative cooling systems. Further information is also available in BS 8580:2010 *Water quality. Risk assessments for Legionella control. Code of Practice*[7] and in The Water Management Society's *Guide to risk assessment for water services*.[8] In summary, the risk assessment should include:

- clear allocation of management responsibilities;
- competence and training of key personnel;
- a description of the water system, including an up-to-date schematic diagram;
- an evaluation of the risk;
- safe operating procedures for the water system, including controls in place to control risks;
- monitoring, inspection and maintenance procedures;
- results of monitoring, inspection and any checks carried out;
- limitations of the legionella risk assessment;
- arrangements to review the risk assessment regularly and particularly when there is reason to suspect it is no longer valid.

Info box: Schematic diagram

A schematic diagram is a simplified but accurate illustration of the layout of the water system, including parts temporarily out of use. While providing only an indication of the scale, it is an important tool as it allows any person who is not familiar with the system to understand quickly and easily their layout, without any specialised training or experience. These are not formal technical drawings but show what the systems comprise, illustrating plant and equipment, including servicing and control valves, any components potentially relevant to the legionella risk, including outlets, strainers and filters or parts that are out of use.

14 If the risk assessment concludes there is no reasonably foreseeable risk or the risks are insignificant and are managed properly to comply with the law, the assessment is complete. Although no further action may be required at this stage, existing controls must be maintained. The assessment of risk is an ongoing process and not merely a paper exercise. Dutyholders should arrange to review the assessment regularly and specifically when there is reason to suspect it is no longer valid. An indication of when to review the assessment and what to consider should be recorded and this may result from, eg:

- a change to the water system or its use;
- a change to the use of the building where the system is installed;
- new information is available about risks or control measures;
- the results of checks indicating that control measures are no longer effective;
- changes to key personnel;
- a case of legionnaires' disease/legionellosis associated with the system.

15 Communication is a key factor in the risk assessment process. The risk needs to be identified and communicated to management to allow them to prioritise remedial actions to control it.

Managing the risk

16 Inadequate management, lack of training and poor communication can be contributory factors in outbreaks of legionnaires' disease. It is important that those people involved in assessing risk and applying precautions are competent, trained and aware of their responsibilities.

17 The dutyholder should specifically appoint a competent person or persons to take day-to-day responsibility for controlling any identified risk from legionella bacteria. It is important for the appointed person, known as the responsible person, to have **sufficient authority, competence and knowledge of the installation** to ensure all operational procedures are carried out in a timely and effective manner.

18 The responsible person appointed to implement the control measures and strategies should be suitably informed, instructed and trained and their suitability assessed. Regular refresher training should be given and the responsible person should have a clear understanding of their role and the overall health and safety management structure and policy in the organisation.

19 If a dutyholder is self-employed or a member of a partnership, and is competent, they may appoint themselves. Many businesses can develop the necessary expertise in house and are well equipped to manage health and safety themselves. However, if there are some things they are not able to do, it is important to get external help. If there are several people responsible for managing risk, eg because of shift-work patterns, the dutyholder needs to make sure that everyone knows what they are responsible for and how they fit into the overall risk management of the system.

20 Identifying and deciding what help is needed is very important but it is the responsibility of the dutyholder to ensure those appointed to carry out the tasks given to them have adequate information and support.

21 Dutyholders can use specialist contractors to undertake aspects of the operation, maintenance and control measures required for their cooling system. While these contractors have legal responsibilities, the ultimate responsibility for the safe operation of the cooling system rests with the dutyholder. It is important they are satisfied that any contractors employed are competent to carry out the required tasks and that the tasks are carried out to the required standards. The contractor should inform the dutyholder of any risks identified and how the system can be operated and maintained safely.

22 There are a number of external schemes to help you with this, such as the Legionella Control Association's *A Recommended Code of Conduct for Service Providers*.[9]

Preventing or controlling the risk

23 First, consider whether the risk of legionella can be prevented by considering the type of cooling systems needed. For example, identify whether it is possible to replace a wet cooling tower with a dry system. Where this is not reasonably practicable and a wet cooling system is the only realistic option available, a course of action must be devised to manage the risk by implementing effective control measures. The written scheme should be specific and tailored to the systems covered by the risk assessment. Appendix 2 summaries the key information, which should include the following precautions:

- ensuring the release of water spray is properly controlled;

- avoiding conditions that support growth of microorganisms, including legionella;
- ensuring water cannot stagnate anywhere in the system by regular movement of water in all sections of the systems and by keeping pipe lengths as short as possible, and/or removing redundant pipework and deadlegs;
- avoiding using materials that harbour bacteria and other microorganisms or provide nutrients for microbial growth (the *Water Fittings and Materials Directory*[10] lists fittings, materials, and appliances approved for use on the UK Water Supply System by the Water Regulations Advisory Scheme. Those approved are tested against BS 6920);[11]
- keeping the system and the water in it clean;
- treating water to either control the growth of microorganisms, including legionella, or limit their ability to grow;
- monitoring any control measures applied;
- keeping records of these and other actions taken, such as maintenance and repair work.

Record keeping

24 Where there are five or more employees, the significant findings of the risk assessment must be recorded. If there are fewer than five employees, there is no requirement to record anything although it is useful to keep a written record.

25 Records must be retained for the period they remain current and for at least two years afterwards, with the exception of records kept for monitoring and inspection, which should be kept for at least five years. It may be helpful to keep training records of employees; records of the work of external service providers, such as water treatment specialists; and information on other hazards, eg chemical safety data sheets.

26 Records, either written or electronic, should contain accurate information about who did the work and when it was carried out. All records should be signed, verified or authenticated by a signature or other appropriate means. Records should include details of the:

- person or people responsible for conducting the risk assessment, managing, and implementing the written scheme;
- significant findings of the risk assessment;
- written control scheme and details of its implementation;
- details of the state of operation of the system, ie in use/not in use;
- results of any monitoring, inspection, test or check carried out, the dates and any resulting corrective actions, as defined in the written scheme of precautions, such as:
  - results of chemical and microbial analysis of the water;
  - water treatment chemical usage;
  - inspections and checks on the water treatment equipment to confirm correct operation;
  - inspections and checks on the cooling system components and equipment to confirm correct and safe operation;
  - records of maintenance to the cooling system components, equipment and water treatment system;
  - the cleaning and disinfection procedures and the associated reports and certificates.

Evaporative cooling systems: Types, design and operation

What is an evaporative cooling system?

1.1 Evaporative cooling of water is widely used to dissipate heat from air conditioning, refrigeration and industrial process systems.

1.2 There is a range of evaporative cooling systems that use evaporation of water to achieve the cooling effect and these include cooling towers and evaporative condensers. Open-circuit cooling towers are the most common and range in size from small packaged towers, used in air conditioning and light industrial applications, up to large towers, including hyperbolic towers, for heavy industrial, petrochemical and power generation applications. All evaporative cooling systems, except for large natural draught towers, have a fan system to force or induce airflow through the unit.

1.3 Although less common, other systems that do not rely solely on the principle of evaporation, are dry/wet coolers or condensers. These systems are able to operate in dry air-cooled mode and wet evaporative cooling mode, but when running in wet mode may present an equivalent risk to a cooling tower or evaporative condenser and may require similar control measures.

1.4 This section gives a detailed description of the characteristics of each type of system, design and construction of evaporative cooling systems; details of their safe operation, commissioning, management and maintenance.

Safe operation and control measures

Design

1.5 A cooling system should be designed with safe operation and maintenance in mind. In particular, it should minimise the release of water droplets and be easily and safely accessible for all essential maintenance tasks. The cooling tower should be designed in a way that readily allows inspection, cleaning and disinfection of all wetted surfaces. Further information on the design of cooling systems is given in paragraph 1.22.

Commissioning and safe start-up

1.6 Systems should be commissioned by adequately trained people in a co-ordinated way to ensure that the system operates correctly as designed. The mechanical and electrical commissioning needs to be co-ordinated with disinfection and cleaning processes and the commissioning of the water treatment system to ensure that the risk of legionella growth and exposure is controlled from the start. Further information on commissioning and safe start-up is given in paragraphs 1.23–1.25.

Operation and maintenance

1.7 A cooling system should be operated in a way that avoids stagnant water conditions and allows the water treatment control measures to be effective. Intermittent operation and duty/standby equipment require particular attention. The system should be maintained to ensure its correct operation and avoid loss of cooling efficiency, which may lead to an increase in microbial growth. Drift eliminators and air inlets need to be maintained to minimise the release of water droplets. There is further information on operating cooling systems in paragraphs 1.26–1.31.

Water treatment

1.8 An effective water treatment programme is an essential control measure to inhibit the growth of legionella in the cooling water. The cooling water treatment programme should be capable of controlling not only legionella and other microbial activity, but also corrosion, scale formation and fouling to maintain the system's cleanliness. Appropriate water treatment may involve a range of chemical and physical techniques to control corrosion, scaling and fouling potential of the cooling water and to control microbial growth. All of these need to be monitored regularly to ensure they remain effective.

1.9 The exact techniques that are required may vary significantly with different water supplies, cooling system design and operating conditions. Paragraphs 1.32–1.74 give further information.

Cleaning and disinfection

1.10 It is a legal duty to control the risk of exposure to legionella bacteria. As legionella are more likely to grow in a cooling system fouled with deposits, maintaining system cleanliness and the water in it is an essential part of the control regime.

1.11 The required frequency and scope of regular cleaning and disinfection operations should be determined by an assessment of the fouling potential. This should be based on inspection and the history of the water treatment control of microbial activity, scaling tendencies and other factors that may result in fouling of the particular system. In relatively clean environments with effective control measures it may be acceptable to extend the period between cleaning operations, provided you can demonstrate that system cleanliness is maintained. Paragraphs 1.77–1.113 contain detailed guidance on cleaning and disinfection techniques and requirements.

Water quality monitoring

1.12 The composition of the make-up and cooling water should be routinely monitored to ensure the continued effectiveness of the treatment programme. The frequency and extent will depend on the operating characteristics of the system. Paragraphs 1.114–1.129 give guidance on analysis and monitoring and suggested details of monitoring schedules.

Types of evaporative cooling equipment

1.13 There is a range of evaporative cooling systems that use evaporation of water as the means of achieving the cooling effect. These include cooling towers and evaporative condensers. Although less common, other systems that do not rely solely on the principle of evaporation are dry/wet coolers or condensers. These dry/wet systems are able to operate in dry air-cooled mode and wet evaporative cooling mode. When running in wet mode, these systems may present the equivalent risk to a cooling tower or evaporative condenser and may require similar control measures.

Cooling towers

1.14 Open-circuit cooling towers are the most common and these can have several different configurations. Figure 1.1 shows one common configuration and illustrates all the main components of an open-circuit cooling tower. Figure 1.2 demonstrates two other common configurations. Commonly, large industrial cooling towers are induced draught counterflow towers, but in air conditioning and light industrial applications, all three configurations are common.

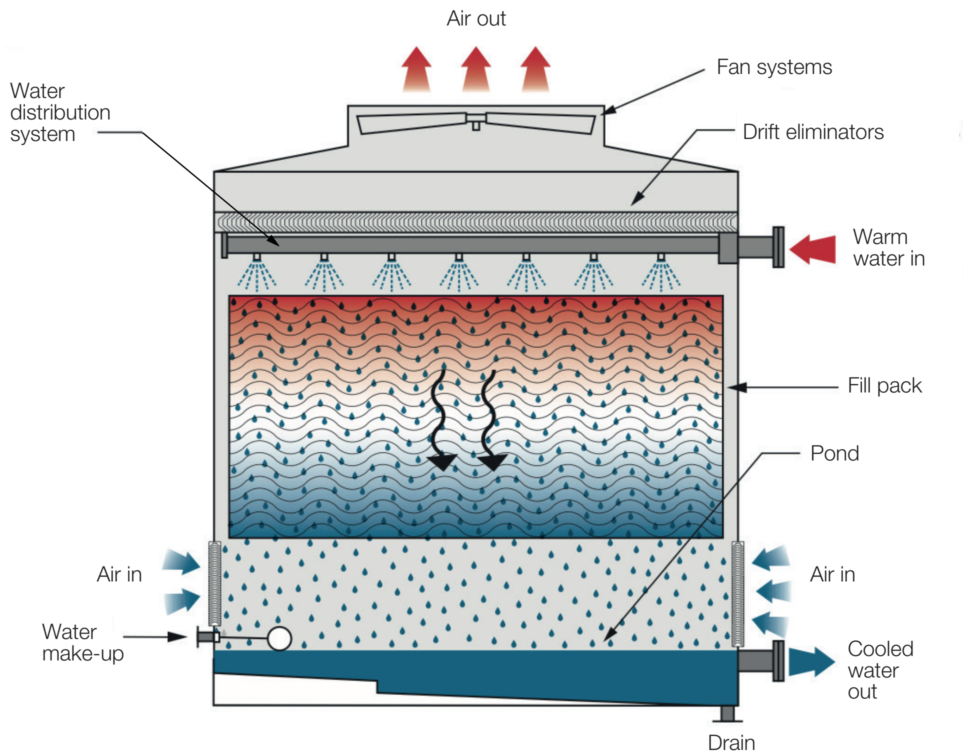


Figure 1.1 Induced draught counterflow cooling tower

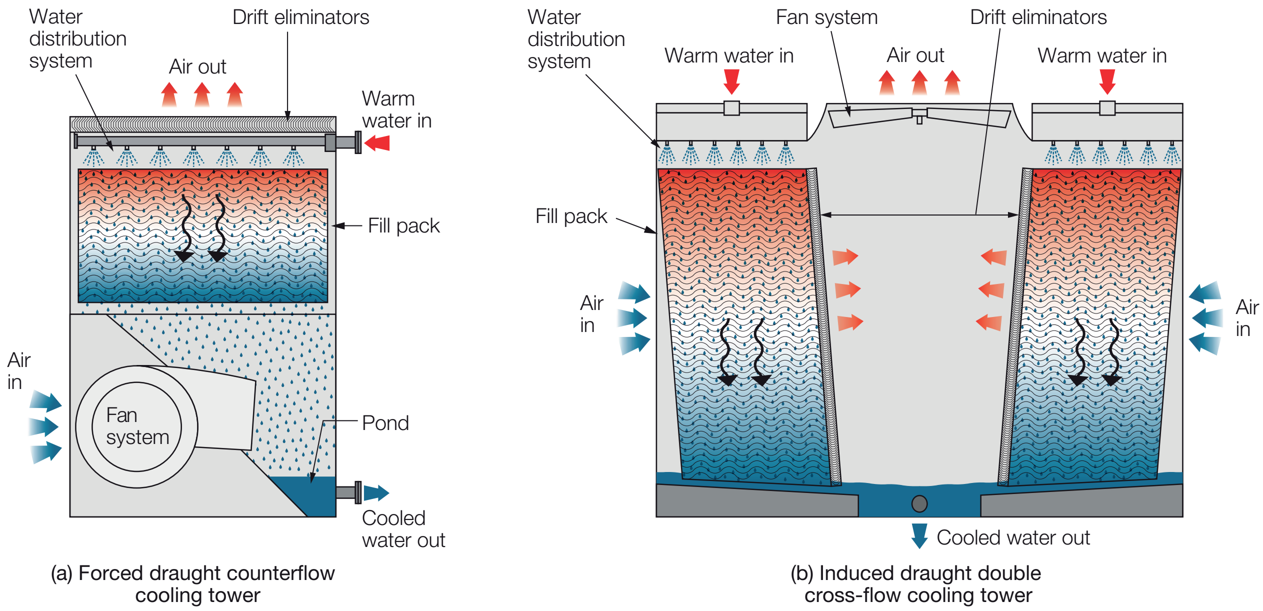


Figure 1.2 Examples of a forced draught counterflow and an induced draught double cross-flow cooling tower

1.15 In an open-circuit cooling tower, the water to be cooled is distributed over a fill pack at the same time as a fan system moves air through the fill pack. This causes a small portion of the cooling water to evaporate which reduces the temperature of the remaining circulating water. The cooled water is collected at the base of the cooling tower and then recirculated to the plant or process needing to be cooled and the warm, humid air is discharged from the tower into the atmosphere.

Evaporative condensers and closed-circuit cooling towers

1.16 Evaporative condensers use the same evaporative cooling principle as cooling towers but incorporate a heat exchanger in which a fluid is cooled by a secondary recirculating system that distributes water over the heat exchange coil and a portion of this water is evaporated (Figure 1.3a). The heat to evaporate the water is taken from the coolant, with the heat being transferred to the water vapour in the air stream, which is discharged into the atmosphere in the same way as a cooling tower. The coolant is often a refrigerant gas but, where the coolant is water or a water/glycol mixture, these systems are sometimes referred to as closed-circuit cooling towers.

1.17 A closed-circuit cooling tower is designed to prevent the water to be cooled from becoming contaminated by coming into contact with the atmosphere. This can be achieved by linking to a separate heat exchanger or by a closed-circuit cooling tower (Figure 1.3b). The latter has a heat exchanger through which the water to be cooled flows and there is a secondary recirculating water system providing the cooling effect in the same way as an evaporative condenser.

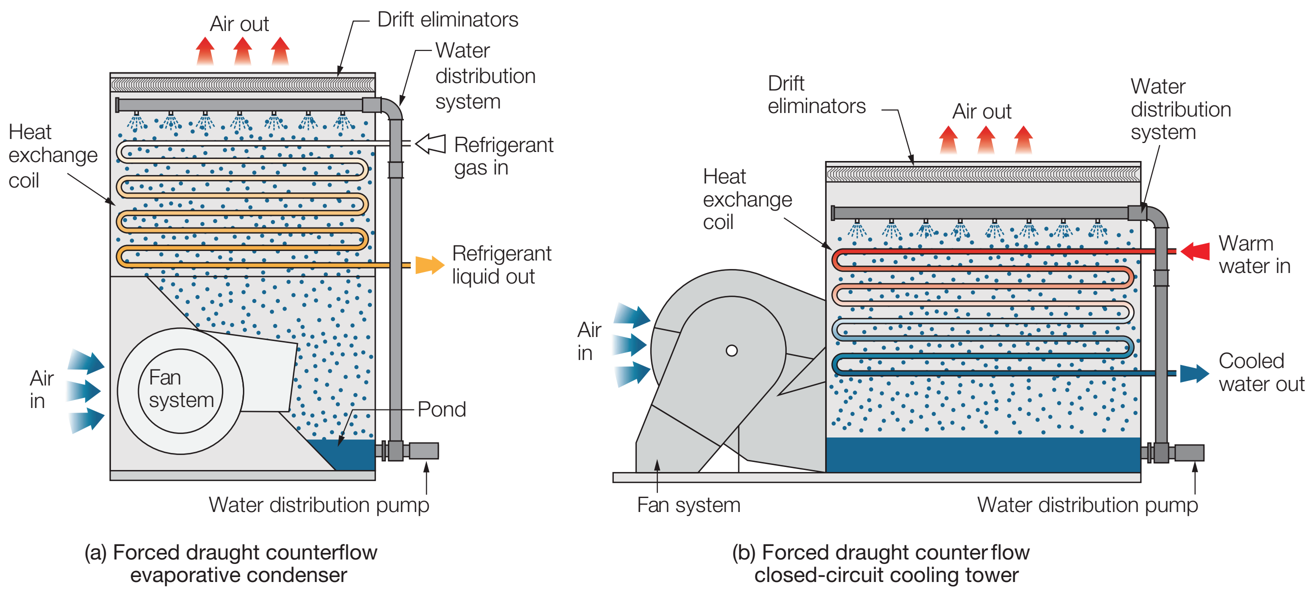


Figure 1.3 Examples of a forced draught counterflow evaporative condenser and a forced draught counterflow closed-circuit cooling tower

Dry/wet cooling systems

1.18 Dry/wet systems, sometimes referred to as hybrid or adiabatic coolers, are able to operate in dry air-cooled mode and wet evaporative cooling mode. They are essentially dry air coolers or condensers that use evaporative cooling to pre-cool the air when demand requires. At low ambient air temperatures or cooling load the unit runs dry without any secondary water flow. As the air temperature or load increases, the unit is switched to wet mode. When running in wet mode, these systems may present an equivalent risk as a conventional cooling tower or evaporative condenser and may require similar control measures. They only use water for evaporative cooling when the ambient air temperature or cooling load is high.

1,19 When in evaporative mode, these systems incorporate a two-stage process. The evaporation of water is used to cool the air entering the cooler, usually by spraying water into the air stream or by trickling it over a medium (eg cellulose pads or plastic mesh) through which the air passes. The cooled air then goes to a conventional dry cooler, increasing its cooling capacity. During the pre-cooling of the air, some or all of the water is evaporated.

1.20 Some of these systems may give rise to significant risk when the spray creates aerosols, or the water sprayed or trickled into the air stream is from a stored water source and/or is collected and recirculated. The risk is reduced when there is no storage or recirculation of water and where generation of aerosols is minimised. The design features of these types of systems are varied, requiring consideration of each on its merits, an assessment of the level of risk posed and the control measures required. Figure 1.4 shows three different examples of dry/wet systems:

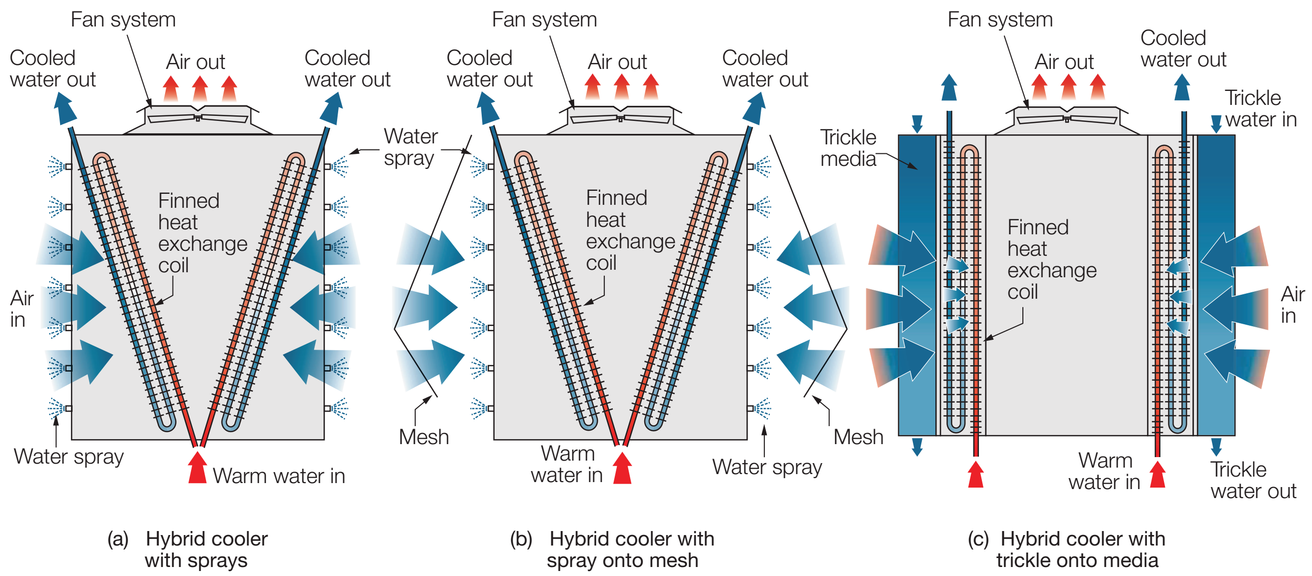


Figure 1.4 Dry/wet cooling systems

1.21 Owing to their different principles of operation, these systems may not require notification under the Notification of Cooling Towers and Evaporative Condensers Regulations 1992 (NCTEC) but it is important to assess the system against the notification requirements defined in NCTEC, eg where such systems spray water directly onto the surface of the heat exchanger.

Info box 1.1: Notification requirements under NCTEC

A ‘notifiable device’ means a cooling tower (a device whose main purpose is to cool water by direct contact between that water and a stream of air) or an evaporative condenser (a device whose main purpose is to cool a fluid by passing that fluid through a heat exchanger which is itself cooled by contact with water passing through a stream of air) except where it contains no water that is exposed to air; where its water supply is not connected; and where its electrical supply is not connected.

Design and construction

1.22 Evaporative cooling systems should be designed and constructed to facilitate safe operation and maintenance, help cleaning and disinfection and control the release of water droplets. In particular, consider the following:

- Cooling towers and evaporative condensers should be made of corrosion-resistant materials that are easy to clean and disinfect. Smaller units are typically constructed from mild steel (with a protective coating), stainless steel or glass reinforced plastic (GRP). Large industrial towers are normally concrete or treated timber construction. Fill packs and drift eliminators are usually made of PVC or polypropylene. The heat exchange coils in evaporative condensers and closed-circuit cooling towers are galvanised steel, stainless steel or copper construction. Construction components made from materials such as natural rubber and untreated timber, which support microbial growth, should be avoided.

- Cooling towers and evaporative condensers require large amounts of fresh ambient air that acts as the medium to remove the heat and which is then discharged into the atmosphere containing water vapour. Towers should therefore be located so that there is an unimpeded supply of ambient air and no obstruction to the exhaust stream from the tower. Ideally, towers should not be located near to any air conditioning or ventilation inlets not close to open windows. There should be adequate space around the tower for routine maintenance and inspection and around gantries or platforms, access doors and hatches, so that all parts of the equipment that require inspection and maintenance can be safely accessed.
- Drift eliminators should be installed in all towers that have fans. Some large natural draught towers have very slow exhaust speeds and the drift loss is negligible. In spite of the name, the function of a drift eliminator is to 'reduce' rather than actually 'eliminate' aerosol drift, although some types are more effective than others. Modern drift eliminators should reduce the drift loss to less than 0.01% of the water flow through the tower.
- In most cases, drift eliminators should be in sections that are easy to handle and readily removable for cleaning. They should be well fitted with no obvious gaps between sections and not damaged. It is important that the airflow is not impeded, eg by build-up of scale. Drift eliminators can become brittle due to chemical attack, ultraviolet radiation from the sun or temperature extremes. Brittleness will lead to breakage of the plastic and this will affect the efficiency of the eliminator. The efficacy of drift elimination is dependent on the relationship between fan speeds, density and resistance of the pack, as well as the design and fitting of the eliminator itself. Care should be taken to ensure that effective drift elimination is maintained and the effects of any alterations to key components of the tower assessed.
- The base tank or pond of cooling towers should be fully enclosed to prevent direct sunlight onto the water. The bottom of the tank or pond should be sloped, or otherwise designed, to facilitate draining with a suitably sized drain connection at the lowest point.
- The air inlets should be designed and protected so as to minimise splash-out or windage losses and to avoid leaves and other contaminating debris being drawn into the tower.
- The water pipework, including balance pipes, should be as simple as practicable, avoiding deadlegs and sections that cannot be drained, which can lead to stagnation, allowing microbial growth. If standby pumps are fitted, any stagnant sections should be flushed with biocide-treated water periodically, typically once every week. If not managed effectively, subsequent disturbance of a deadleg may result in rapid colonisation of the whole system. The pipework should be constructed from materials compatible with the evaporative cooling equipment to reduce the possibility of corrosion.
- Cleanliness of the tower and associated plant is vital for the safe operation of a cooling system and effective cleaning should be carried out periodically. All wetted parts such as the internal surfaces of the tower, drift eliminators, water distribution system and fill pack should be accessible for an assessment of cleanliness and cleaned as needed.
- The tower should be made of materials that do not support microbial growth and can be readily disinfected. Treated timber may still be used in the

manufacture of the cooling towers but it needs to be resistant to decay and easy to clean and disinfect.
- Control of the operating water level in a cooling tower is important to prevent overflow or splash-out, which can affect treatment chemical levels and also result in the release of aerosols. Water level is often controlled by a mechanical float-operated valve, which works well for continuously operated towers. Electrical water-level devices are recommended for more precise level control and for towers that are shut down more frequently than once every quarter.
- Tower fans are commonly automatically controlled by frequency inverters which ensure that the fan speed responds to the system load. Frequency inverters also regulate the air speed through the drift eliminators, which in turn will limit the amount of drift exiting from the tower.

Commissioning

1.23 Commissioning of cooling systems is an essential step in ensuring they operate safely from the outset. Cases of legionellosis have been associated with systems that were not clean or properly commissioned before being put into operation.

1.24 Systems should be commissioned to ensure they operate correctly and safely in accordance with the design parameters. It is essential that the commissioning process is carried out in a logical and defined manner in full compliance with the supplier's or installer's instructions and includes both the evaporative cooling equipment itself as well as any associated pipework and water treatment plant. The responsibilities of the staff carrying out the commissioning process should be clearly defined with adequate time and resources allocated to allow the integrated parts of the installation to be commissioned correctly. The precautions taken to prevent or control the risk of exposure to legionella during normal operation of cooling systems also apply to the commissioning process.

1.25 When scheduling commissioning (or recommissioning) of a tower, note the following:

- Commissioning should not be carried out until the system is required for use and it should not be charged with water until commissioning takes place. If filled for hydraulic testing, the system should be drained and not refilled until commissioning takes place.
- If a new system is to be taken into use within a week, commissioning can be carried out and the system left charged with treated water, which should include a biocide.
- Record the results of the commissioning process and include them as a section in the operation and maintenance manual. The availability of such baseline data enables periodic checks to be made to show that the installation continues to operate as intended.
- Formal arrangements should be made to check that commissioning has been completed to the standard specified, eg an independent engineer witnesses the testing and countersigns the relevant documents.

Management of cooling systems

1.26 A cooling system consists of a cooling tower, evaporative condenser or other cooling equipment, together with pumps, recirculation pipework and valves and usually the heat exchanger or condenser. It may also include ancillary items, such as make-up supply tanks, pre-treatment plant and the chemical dosing system. All these items need to be considered and included in the management and control scheme of the system, including:

- correct operation and maintenance – this is the basic requirement for ensuring the safety of the system;
- cleanliness – keeping the system clean reduces the possibility of it harbouring bacteria and their uncontrolled growth and will allow effective application of elements of the water treatment regime, such as biocide dosing;
- suitable water treatment – this minimises the opportunity for bacteria to proliferate within the system as well as controlling scaling, corrosion and fouling;
- effective drift eliminators – these act as the last line of defence, minimising the loss of potentially infectious aerosols if there is a failure of the water treatment regime.

Operation

1.27 The cooling system should be kept in regular use whenever possible. When a system is used intermittently, arrangements should be in place to ensure that treated water circulates through the entire system this should be monitored and records kept. The system, including the fans, should run for long enough to distribute the treated water thoroughly.

1.28 If a system is to be out of use for a week or longer, eg up to a month, biocides should continue to be dosed and circulated throughout the system, at least weekly. If a system is to be out of use for longer than a month it should be drained and shut down. The system, including the water treatment regime, should be recommissioned before reuse.

1.29 An operation and maintenance manual should be available for the whole system and include the manufacturers' instructions for all individual pieces of equipment, and details of:

- operation and maintenance procedures that enable plant operators to carry out their duties safely and effectively;
- checks of equipment as fitted;
- the system as currently in operation;
- schematic diagram and total water volume of the system;
- specific information on the water treatment programme;
- normal operation control parameters and limits;
- required corrective actions for out-of-specification situations, such as when plant operating conditions or the make-up water quality change;
- cleaning and disinfection procedures;
- monitoring records of the system operation.

Maintenance

1.30 Preventive maintenance is an important measure to assure reliable and safe operation of the cooling system. The operation and maintenance manual should include a detailed maintenance schedule, listing the various time intervals when the system plant and water should be checked, inspected, overhauled or cleaned. The completion of every task should be recorded by the plant operatives.

1.31 Drift eliminators require particular attention with regard to maintenance. To remain effective, they should be regularly inspected to ensure they are clean, properly positioned and not damaged.

Requirements of a cooling water treatment programme

1.32 An effective water treatment programme should be established based on the physical and operating parameters for the cooling system and a thorough analysis of the make-up water. The components of the water treatment programme should be environmentally acceptable and comply with any local discharge requirements.

1.33 This section covers the key principles involved in the development of a suitable cooling water treatment programme for the control of legionella and offers guidance on how to treat water in cooling systems.

Desired outcomes

1.34 An appropriate cooling water treatment programme must be capable of controlling not only legionella and other microbial activity, but also corrosion, scale formation and fouling, and include appropriate measures, such as regular physical cleaning and disinfection, to maintain the system's cleanliness. This is very important since these aspects are often interrelated and failure to control one aspect will often lead to other problems and will increase the legionella risk.

1.35 The water treatment programme should be capable of delivering certain desired outcomes. Table 1.1 shows the typical cooling water desired outcomes. These outcomes will depend on the nature of the water and the system being treated. The particular desired outcomes and the metrics to be used should be agreed between the system owner/operator and their specialist water treatment service provider.

Table 1.1 Typical cooling water desired outcomes

Aspect of control	**Desired outcome**
Microbial activity, as estimated by dip slides or TVCs (total viable counts) at 30 ^{0}C (minimum 48 hrs incubation)	Not greater than 1 x 10^4 cfu/ml (colony forming units per millilitre)
Legionella	Not detected or not greater than 100 cfu/l
Corrosion of carbon steel	Generally less than 5 mpy and preferably less than 2 mpy
Scale control	No significant loss of hardness from solution (eg a calcium balance of >0.9) Minimal visible deposition of hardness salts on pack or other surfaces and no significant loss of heat transfer efficiency as a result of deposition
Physical fouling and system cleanliness	Bulk water should be visually clear and the frequency of physical cleaning and disinfection should reflect the tendency of the system to build up fouling deposits as a result of airborne or process contamination or microbial growth

Info box 1.2: Scientific (or standard) notation

Scientific notation is a compact way of expressing either very large or very small numbers and makes the number easier to work with. The format for a number in scientific notation is the product of a number (integer or decimal) and a power of 10 and is simple to express, as shown in the examples used in this guidance: 10^4 = 10 000, 10^3 = 1000.

Microbial control

1.36 The operating conditions of a cooling system provide an environment where microorganisms can proliferate. The water temperatures, pH conditions, concentration of nutrients, presence of dissolved oxygen, carbon dioxide and daylight, together with large surface areas, all favour the growth of microorganisms such as protozoa, algae, fungi and bacteria, including legionella.

1.37 Problems arise when microorganisms are allowed to grow to excess. This can result in the formation of biofilms on system surfaces. These can:

- cause a reduction in heat transfer;
- harbour and protect legionella and provide an environment for their growth;
- induce highly localised microbial corrosion;
- interfere with the effectiveness of corrosion inhibitors;
- trap particulate matter, increasing the problem of fouling;
- disrupt water distribution within the tower.

1.38 Both surface-adhering (sessile) and free-flowing (planktonic) bacteria need to be controlled for a complete and effective programme. Microbial activity is generally controlled by using biocides, which are chemical additives that kill microorganisms. Whatever biocide regime or other microbial control measure is used, it should be capable of maintaining consistently low aerobic counts, often referred to as total viable counts (TVCs) and prevent the proliferation of legionella.

Corrosion control

1.39 In many cooling systems, a significant proportion of the construction material is mild steel, which is susceptible to corrosion. Although heat transfer equipment may be made of more corrosion-resistant metals such as copper, copper alloys or stainless steel, these metals also need to be adequately protected. Corrosion of mild steel, in particular, should be inhibited as it may lead to conditions that encourage the growth of legionella.

1.40 Good corrosion control requires a clear understanding of the cooling water chemistry and metallurgy, the selection of a corrosion inhibitor matched to that chemistry and metallurgy and adequate control of both the inhibitor and the chemistry within the system. As with all cooling water analysis a suitably trained and competent person should interpret the results.

Info box 1.3: Corrosion rates

Corrosion rates are commonly expressed in mpy (mils per year) where a mil is 1/1000th of an inch penetration. The metric units for corrosion rates are mm/a (millimetres per annum), and as an example, a corrosion rate of 1.0 mpy is the same as 0.0254 mm/a. These general values are for 'typical' cooling systems with 'typical' waters. For certain process cooling applications different corrosion level targets (either higher or lower) may be appropriate. Corrosion control will normally be achieved either by adding specific corrosion inhibitors or by allowing the cooling water to concentrate to a point where it becomes less corrosive but more scale-forming in nature, and treated with appropriate scale inhibitors and dispersants.

Corrosion rates can be determined using metal corrosion coupons or electronic instrumentation. Such analysis is not typically included in a water treatment programme for smaller cooling systems unless it is a contractual requirement, but it is considered good practice. The measurement of total iron levels in the recirculating water can give some indication of corrosion activity, but because iron readily oxidises in an oxygenated environment to form insoluble deposits, the result is open to misinterpretation. A typical control limit for total iron would be less than 1.0 mg/l and while a higher level may well be an indication of inadequate corrosion control, a level of less than 1.0 mg/l does not definitively indicate good corrosion control.

1.41 Corrosion and scale inhibitors should be applied continuously and be capable of producing the desired control over corrosion and scaling. For liquid inhibitors a commonly employed method of addition is using a dosing pump controlled by a water meter installed on the cooling system make-up water supply. In situ monitoring of treatment reserves, with feedback control of dosing, can also be employed.

1.42 Inhibitor formulations can be supplied as a single multi-functional product incorporating a number of corrosion and scale inhibitors, and dispersant polymers to reduce fouling tendencies. For some large cooling systems, it can be more cost effective, and provide greater flexibility, if the required components are supplied and dosed separately.

Scale control

1.43 Scale is the localised precipitation of normally water-soluble inorganic hardness salts. Its formation is influenced by the concentration of calcium salts, pH, surface and bulk water temperatures and the concentration of the total dissolved solids. As an evaporative cooling system operates, the concentration of these various dissolved solids increases and the pH of the water tends to rise, which results in the scaling potential of the water increasing.

1.44 Scale formation results in loss of heat transfer, reduced flow rates and loss of efficiency, and contributes to deposition. Legionella can be associated with such deposits. The scale protects the bacteria and so reduces the effectiveness of any biocidal treatment.

1.45 One or more of the following techniques generally control scale formation:

- removing the hardness from the make-up water by pre-treatment, eg water softening;

- adding specific scale inhibitors that extend the solubility of the hardness salts and so prevent precipitation;
- acid dosing to lower the pH and alkalinity and reduce the scaling potential;
- limiting the system concentration factor to a range within which the hardness salts can remain soluble.

Info box 1.4: Scaling index

The scaling tendency of a given water can be predicted by calculating the Langelier Saturation Index or Ryznar Stability Index. Assessing control of scaling can be made using tools such as calcium balance, which estimates how much of the calcium hardness entering the cooling system is being maintained in solution. As with all cooling water analysis, a suitably trained and competent person should interpret the results.

Fouling control and physical cleanliness

1.46 'Fouling' is normally applied to deposition of particulate material and debris such as:

- insoluble corrosion products;
- scale deposits;
- mud, silt, clay;
- airborne dust and debris;
- process contaminants;
- biological matter such as insects, pollen and plant material, and the formation of biofilm.

1.47 Settlement will occur in low-velocity areas of the system and can lead to loss of plant performance, corrosion under the deposits, increased microbial activity and proliferation of legionella. In systems using make-up water that has a high concentration of suspended solids, pre-clarification may be needed.

1.48 Fouling tendencies can be controlled by adding specific dispersant chemicals to keep suspended solids mobile and may be helped by incorporating side-stream filtration which filters a proportion of the circulating water and then returns it to the cooling circuit. The frequency of disinfection and cleaning operations should be determined by the tendency for parts of the system such as sumps and the pack to become fouled with accumulated deposits. An evaporative cooling system is, in effect, an air scrubber, so some build-up of deposits with time is inevitable and periodic removal of these deposits is an important measure in the control of legionella.

1.49 Effective water treatment can significantly reduce the fouling in a cooling system and the history of control of the fouling factors and water treatment programme should be used in conjunction with inspection to determine the frequency and type of cleaning and disinfection operations to be carried out.

1.50 Off-line disinfection and cleaning is not an end in itself. The desired outcome is system cleanliness, and if this can be achieved effectively by other means on an ongoing basis, this is acceptable.

Conventional chemical water treatment

1.51 Most cooling systems are treated using what might be termed conventional chemical techniques. This may involve adding inhibitors to control corrosion and scale formation, biocides to control microbial growth and dispersants to control fouling. These may be in the form of single-function chemicals or multi-functional admixtures.

1.52 The chemical programme can be augmented by pre-treatment of the make-up water and will include bleed-off control to limit the cycles of concentration. In some instances, acid dosing may be incorporated as part of the scale control programme and in other instances side-stream filtration may be employed to control the build-up of suspended solids.

1.53 This chemical treatment programme should be carefully selected based on the cooling system design, size (ie the water chemistry in smaller volume systems may be more difficult to maintain) and operating conditions, the make-up water analysis, materials of the system construction and environmental constraints. The different elements of the treatment programme should be chemically compatible.

1.54 The treatment programme should be capable of coping with variations in the operating conditions, make-up water analysis and microbial loading.

1.55 Chemical dosage and control should be automated where possible to ensure the correct treatment levels are consistently applied and to minimise exposure of operators to chemical hazards. For each chemical. there should be a safety data sheet, a completed COSHH risk assessment and control measures applied for their safe handling and use.

Biocides

1.56 The biocide regime should be capable of controlling the microbial activity in the cooling water consistently, so the TVC of aerobic bacteria is maintained at no greater than 1×10^4 cfu/ml (colony forming units per millilitre) and other problematic microbes are controlled. The ease with which this can be achieved will vary from system to system depending on the operating conditions and particularly the availability of nutrient in the water to support microbial growth.

1.57 The dosage and control of the biocide regime should be automated to ensure the correct quantity of biocide is applied at the required frequency. The dosage of oxidising biocides, such as bromine and chlorine, can be controlled by a redox or amperometric control system, which automatically adjusts the dosage in response to the oxidant demand of the water to maintain the desired biocide residual level.

1.58 An advantage of oxidising biocides is that they can be monitored by a simple field test to measure the residual biocide in the cooling water, whereas the concentration of non-oxidising biocides cannot easily be measured directly.

1.59 Biocides are applied routinely at the tower pond or the suction side of the recirculating water pump, but should be dosed so that the biocide will circulate throughout the cooling system. However, in air conditioning systems where the tower can be bypassed, the biocide needs to be added to the suction side of the recirculating pump. Whatever method is used, it should ensure good mixing and avoid localised high concentration of chemical, which may cause corrosion.

1.60 The effectiveness of the biocide regime should be monitored weekly, conventionally by using appropriate microbial dip slides (although alternative technologies that do not rely on culturing bacteria also allow analysis of microbial activity), and specific sampling for legionella should be done on at least a quarterly basis. Adjustments to the dosage and control settings may be needed in response to any high count. More frequent sampling may be needed for other reasons (see paragraph 1.126).

Info box 1.5: Biocide types and application

Oxidising biocides

The oxidising biocides most commonly used in cooling water are those based on compounds of the halogens chlorine and bromine and may be supplied as solid tablets, granules or powder, or as solutions. On dilution these compounds form the free halogen species hypochlorous acid (HOCl), hypobromous acid (HOBr), hypochlorite ion (OCl^-) and hypobromite ion (OBr^-) in a pH-dependent equilibrium.

This pH-dependent relationship is important because the hypochlorous and hypobromous acids are more active biocidally than the hypochlorite and hypobromite ions and the concentration of these active acids declines with rising pH. As the pH of cooling water rises and becomes increasingly alkaline, chlorine compounds tend to become less biocidally active and slower acting, whereas bromine compounds retain much of their activity. For this reason the use of chlorine-based biocide programmes tend to be restricted to larger cooling systems operating at lower cycles of concentration or those employing pH control. Bromine-based biocide programmes are generally considered more appropriate for smaller cooling systems and any system where the cooling water pH is likely to exceed pH 8.

A chlorine-based programme can effectively be converted to a bromine-based programme by adding an inorganic bromide salt, which converts the hypochlorous species to the hypobromous equivalent with a requisite increase in biocidal activity at higher pHs.

Halogen-based biocides are typically applied to establish a measurable reserve using DPD No1, in the range 0.5–1.0 mg/l as Cl_2 or 1.0–2.0 mg/l as Br_2. In some circumstances, it may be possible to maintain good microbial control at a lower halogen reserve and in other circumstances, such as more alkaline pH conditions, it may be necessary to increase the halogen reserve to compensate for the reduction in biocidal activity. You should monitor the effectiveness of the microbial control using weekly dip slides and periodic legionella analysis (see the control values in Tables 1.8 and 1.9) and adjust the target biocide reserves accordingly.

It is preferable that oxidising biocides are applied continuously or in response to a redox or amperometric control system, pre-set at a level equivalent to the correct halogen reserve required. If, however, halogen biocides are shot dosed, they should be dosed sufficiently often and in sufficient quantity to maintain good microbial control at all times (see the control values in Tables 1.8 and 1.9).

Oxidising biocides are aggressive chemicals and if overdosed will lead to increased corrosion rates. High concentrations of oxidising biocides can also degrade other cooling water chemicals, such as inhibitors, so it is important that the dosing arrangements are designed to ensure the two chemicals do not mix until they are well diluted, ie in the system.

Owing to their mode of action, oxidising biocides are not prone to developing microbial resistance, so it is not normally necessary to dose a second biocide alternately, unless the oxidising biocide is dosed infrequently. However, bio-dispersant chemicals, which are special surfactants, are often applied in conjunction with oxidising biocides to help the penetration and dispersion of biofilms. While it is not normally necessary to dose a secondary biocide where an oxidising biocide is applied continuously, it may be appropriate to control a particular microbial problem such as algal growth in areas of the cooling tower exposed to sunlight.

Used correctly, both chlorine and bromine biocide programmes are extremely effective at controlling the general microbial count and preventing the proliferation of legionella even where significant nutrient levels are present. Their efficacy can, however, be affected by certain process contaminants such as ammonia or very high organic loading. Under such circumstances an alternative oxidising biocide such as chlorine dioxide or an appropriate non-oxidising biocide programme may be used.

The performance of chlorine dioxide as a biocide is not affected by the water pH, it does not react with ammoniacal compounds and it is often less affected by organic contamination than either chlorine- or bromine-based oxidising biocides. It is extremely effective at penetrating and dispersing biofilms. However, it is more complex to dose and its volatility means that maintaining a measurable residual of chlorine dioxide in the recirculating water downstream of the cooling tower may prove difficult. It tends therefore to be used as a niche biocide for applications where contamination precludes the use of chlorine or bromine. When it is used, it may either be dosed continuously at a low level or intermittently at a higher level with the frequency and dosage level often being determined by the results of microbial monitoring rather than by achieving and maintaining a specific chlorine dioxide residual.

Non-oxidising biocides

Non-oxidising biocides are organic compounds that are usually more complex than oxidising biocides. They are generally more stable and persistent in the cooling water than oxidising biocides, but their concentration will reduce with time because of system water losses and degradation and consumption of the active material.

To achieve the right non-oxidising biocide concentration to kill microorganisms, biocide is normally added as a shot dose. The frequency and volume of applications are dependent on system volume, system half-life, re-infection rate and the required biocide contact time, typically at least four hours. These need to be considered to ensure that the biocide concentration necessary to kill the microorganisms is achieved. In systems with smaller water volumes and high evaporation rates it is particularly important that the above parameters are accurately determined. In the case of systems that have long retention times, the half-life of the biocide is the controlling factor. The total system volume should be established to ensure that the desired levels of non-oxidising biocides are applied.

A non-oxidising biocide programme should use two biocides with different kill mechanisms on an alternating basis to minimise the risk of the microbial flora evolving into a population tolerant to a single biocide type. Once the concentration of any biocide has been depleted to below its effective level, the system will be open to infection. The efficacy of non-oxidising biocides may be influenced by the pH and temperature of the water in the system and this should be taken into account to ensure that the biocide programme is effective. The following points are important in selecting a non-oxidising biocide programme:

- retention time and system half-life;
- cooling water analysis, eg pH;
- microbial populations;
- system dynamics;
- system contaminants;
- handling precautions;
- effluent constraints;
- considering if an oxidising biocide programme is more appropriate.

Pre-treatment

1.61 Make-up water is normally mains water but can be supplied from various sources, such as rivers, lakes and boreholes, or even from within the process itself. These sources may require pre-treatment to reduce contamination and improve the quality to that approaching mains supply. If not pre-treated to mains quality then the water entering the system will often be subject to considerable variations in suspended solids, total dissolved solids and microbial composition. This should be considered in the risk assessment for the cooling system and a strategy will be required to manage it.

1.62 Pre-treatment may take the form of filtration or clarification to remove suspended solids, disinfection to reduce the microbial population, reverse osmosis to reduce the dissolved solids or softening to reduce the hardness level and scaling potential.

1.63 Water softening is often used as a pre-treatment in hard water areas and can prevent scale formation effectively. However, removing all the hardness significantly increases the corrosivity of cooling water. This can be extremely damaging to the cooling equipment and may invalidate the manufacturer's warranty. It is common therefore to blend a proportion of hard water back into a softened make-up water supply. Reverse osmosis permeate is also occasionally used to provide softened make-up water to cooling systems. Without blending back of some hardness and alkalinity salts, this water is even more corrosive than softened water.

Intermittently operated systems and standby equipment

1.64 Cooling systems that remain idle for more than a few days or that are held on wet standby for use at short notice should be dosed with an appropriate biocide and circulated to ensure thorough mixing at least once a week.

1.65 Where a system has duty and standby equipment such as circulation pumps, these should all be operated during the circulation period to ensure that the biocide reaches all parts of the system and to avoid stagnation.

1.66 Where part of a system, eg a chiller plant, is brought back into service after a period of being on standby, the whole system should be dosed with biocide. It may be desirable to maintain higher levels of chemical treatments, particularly corrosion inhibitors, at such times.

Alternative treatment techniques

1.67 There are a number of alternative techniques of water treatment available and these methods of control are sometimes used singularly as a stand-alone technology or in combination with traditional chemical biocides. As with the application of water treatment chemicals, owners/operators of cooling systems will need to monitor the efficacy of such control processes since the appropriateness and effectiveness of these techniques can vary significantly. The owner/operator of the cooling system should verify that the proposed technique is suitable for the particular application, taking into account the specific make-up water characteristics, operating conditions and desired outcomes. The alternative techniques of water treatment available include the following.

Ultraviolet irradiation (usually used in conjunction with a biocide)
1.68 UV irradiation has been used to treat water systems for many years, particularly where the water is 'highly polished', ie good quality with little suspended solids and hardness. This physical control process uses the UV part of the electromagnetic spectrum (between visible light and X-rays) to cause damage to the microorganism's cellular genetic material (DNA). At a wavelength of 265 nm, UV is found to be most effective. Typically used in conjunction with a filtration device upstream of the UV lamp in domestic water services, in cooling systems UV is more frequently used in conjunction with a chemical biocide. The quality of the cooling water is an important consideration, as hardness and iron can lead to scaling or staining of lamp surfaces.

Use of ozone
1.69 Ozone can be used as a fast-acting, rapidly dissipating biocide which exhibits broad spectrum antimicrobial activity. Within cooling system applications, the potential for a short half-life due to rapid decomposition may result in areas of the system remaining untreated. This will be prevalent especially in the remote parts of a large cooling system with a long holding time. Also consider the reactivity of ozone with other system treatment products (eg scale and corrosion inhibitors).

Electromagnetic/pulsed electric field technologies
1.70 This technology is based on pulses of electromagnetic energy inactivating/disrupting the cellular structures within microorganisms. The production of 'free radicals' on exposure to electromagnetic pulses is also thought to contribute to antimicrobial action by electrochemical reaction.

Ultrasonics and cavitation
1.71 The interaction of ultrasonic energy with water results in cavitation processes, generating cavitation bubbles, which when they collapse can lead to inactivation of microorganisms. This process is called sonication. This process is short lived and so the treatment programme used often incorporates a chemical application too.

Filtration technologies
1.72 By nature of their action, cooling systems may suffer considerable levels of system contamination, either by suspended solids in the make-up water, or the 'scrubbing action' of cooling towers, or by process leaks encouraging microbial activity. Side-stream filtration, where a volume of recirculating cooling water is passed through a 'side-stream' loop, is commonly employed in large cooling systems where the plant operates continuously, but the principle may be employed in most cooling systems, usually depending on economic justification.

Establishing performance criteria for microbiological control programmes

1.73 Whatever means is used for microbial control, it should be monitored rigorously to ensure control is maintained. Where possible, performance criteria for other non-chemical techniques should be established and monitored.

1.74 When introducing an alternative treatment technique, more frequent microbial monitoring should be considered until control is established.

Inspection, cleaning and disinfection procedures

1.75 Maintaining the cleanliness of the cooling system and the water in it is critical to prevent or control the risk of exposure to legionella. This section gives guidance on when and how to inspect, clean and disinfect a cooling system.

1.76 Decisions about the frequency and scope of inspection and cleaning operations and whether a cooling system is clean enough for operation are ultimately the responsibility of the responsible person. They may seek advice and help from specialist service providers for water treatment, risk assessment, cleaning and disinfection.

Why is it important to clean and disinfect the cooling system?

1.77 Legionella are more likely to proliferate in water systems that are fouled with deposits and biofilm that can protect the organisms from water treatments and provide nutrients for them to multiply. So maintaining system cleanliness is crucial.

1.78 Effective water treatment measures can reduce the rate at which a cooling system becomes fouled, however, an evaporative cooling system will inevitably accumulate airborne dust from the atmosphere and may be subject to contamination originating from the process for which the system provides cooling. It is therefore necessary to take cooling systems out of service periodically for physical, and possibly chemical, cleaning to remove this fouling.

When and how often should a cooling system be cleaned and disinfected?

1.79 If a system can be shown to be free from fouling, ie the deposition of particulate material and debris, there is no need for it to be cleaned at a set time interval, rather the system should be cleaned whenever it is known or suspected to have become fouled. However, as cleaning operations are disruptive, it is common to adopt a precautionary approach, with cleaning operations being scheduled to coincide with planned shutdowns or at a predetermined interval, eg six monthly.

1.80 A cooling system should always be inspected, disinfected and, if required, cleaned if there is a significant change in operation status such as:

- immediately before the system is first commissioned;
- after any prolonged shutdown of a month or longer (a risk assessment may indicate the need for cleaning and disinfection after a period of less than one month, especially in summer and for health care premises where shutdown is for more than five days);
- if the tower or any part of the cooling system has been physically altered, eg refurbishment or replacement of pumps, pipework or heat exchangers.

1.81 The tendency of the system to become fouled either with waterborne foulants or airborne contaminants will inform how often cleaning takes place. Systems should be cleaned whenever an inspection indicates the need or in response to circumstances resulting in contamination or increased fouling, such as process contamination, local construction work or an increase in the turbidity of the make-up water source.

1.82 Where a cooling system operates continuously, and it is therefore only possible for the system to be completely shut down infrequently, additional control measures and monitoring may be required to ensure cleanliness and minimise the risk. Such measures may include:

- continuous automated dosage and control of oxidising biocide;
- maintaining the correct pH level when using oxidising biocides;
- dosage of additional dispersants and biodispersants;
- side-stream filtration, possibly linked to a cooling tower basin sweeping system;
- more frequent microbial monitoring (eg monthly legionella sampling);
- online disinfection procedures;
- partial system shutdowns (eg single cooling tower cells) to allow inspection and cleaning of that part of the system.

When and how often should a cooling system be inspected?

1.83 Effective water treatment will slow the rate of fouling but will not completely eliminate it or prevent fouling caused by airborne contamination. It is therefore necessary to inspect parts of the cooling tower system regularly to determine the cleanliness, need for cleaning and type of cleaning process required. Provision should be made to allow access to these parts safely.

1.84 The frequency with which these inspections should be scheduled will vary depending on the fouling potential and should be determined by the history of previous cleans and an assessment of the likelihood of fouling, based on the water treatment history and the environment in which the cooling tower is operating. The following timescales, though not prescriptive, can be considered typical for different situations:

- at least every 3 months for a cooling system in a dirty environment (eg a tower that is prone to process or environmental contamination);
- at least twice a year for an air conditioning comfort cooling system;
- at least every 12 months for a 'clean' industrial application and any others.

1.85 Paragraphs 1.114-1.129 provide guidance on the tests for monitoring water quality and water treatment analytical reports. The responsible person and their water treatment provider should review the results jointly and agree any necessary actions. In addition to the monthly water treatment reports, Table 1.2 illustrates how the history of the water analysis and other fouling factors might help decide how often to inspect and clean the system and predict the risk of an increase in fouling over a period.

Table 1.2 Example of how to use water analysis results and other fouling factors to predict risk of fouling

	Indicator (where applicable)	Good	Probably acceptable	Caution	High risk	Notes on interpretation
Microbial control indicators	Average dip slide/ TVC values	10^3 cfu/ml	10^4 cfu/ml	10^5 cfu/ml	10^6 cfu/ml	The higher the TVC, the greater the risk of biofilm formation/biofouling. An occasional high value is generally not a major concern provided the normal value is low
	Average bromine or chlorine (ppm)	>1.0 Br_2 or >0.5 Cl_2	0.5–1.0 Br_2 or 0.25–0.5 Cl_2	0.25–0.5 Br_2 or 0.1–0.25 Cl_2	0	With oxidising biocides like bromine or chlorine, maintaining a consistently good reserve minimises the risk of biofouling and controls potential legionella growth. Different values may apply for other oxidising biocides and the general principle of good control minimising fouling and legionella growth potential applies to any biocide regime. If the dip slide readings are high, the biocide regime is not effective
	Legionella +ve (per 4 samples)	0/4	0/4	1/4	2/4	The absence of legionella does not indicate the absence of risk. Sporadic legionella positive results are not uncommon (even with low TVCs) and, provided the TVCs and biocide control are good, are not normally a major cause for concern. However, repeated legionella positives or positives plus poor biocide control and/or poor TVCs are and should be investigated
Scaling risk indicators	Average LSI (actual and theoretical calculation based on cycled up make-up water)	1	1.5	2	2.5	As the LSI increases the risk of scale formation increases, however, a good scale inhibitor is capable of preventing scale formation up to an LSI of +2.5 and possibly beyond. Equally, with poor inhibition scale formation is likely at lower LSIs. Ideally, a comparison should be made between the actual measured LSI and the calculated theoretical LSI based on cycled up make-up water to ensure that they are similar. If the actual value is substantially lower than the theoretical value, it indicates loss of hardness from solution and so scale formation may be occurring. This indicator should be used in conjunction with the calcium balance, knowledge of the performance capabilities and history of control of the inhibitor to decide the likelihood of fouling with scale. This indicator is not valid for fully softened make-up water but a history of efficient softener operation will be adequate to ensure a low risk of scale formation
	Average calcium balance	>0.95	0.9	0.8	<0.75	The calcium balance only applies for unsoftened water and is an indicator of whether the hardness is being retained in solution or is possibly depositing on heat transfer surfaces or the packing. The lower the calcium balance, the more likelihood that scale formation is occurring
	Average level inhibitor as % of target	100% +	90%	80%	<50%	Poor control over the inhibitor significantly increases risk of scale formation and corrosion

Table 1.2 Example of how to use water analysis results and other fouling factors to predict risk of fouling (continued)

Other foulant risk indicators	Silt/suspended solids level in incoming water	Absent	Light	Moderate	Significant	High levels of silt or suspended solids in the incoming water supply can cause heavy fouling. This risk can be generally considered absent with mains water, but may be very significant with some surface water and industrial water supplies
	Process contamination	Absent	Light	Moderate	Significant	The fouling potential will depend on the nature of the contamination. Some contaminants may foul in their own right, whereas others may be a nutrient source for microbial activity, which if not adequately controlled could lead to significant biofouling. This risk factor is likely to be absent in comfort cooling and many light industrial applications
	Potential for atmospheric dust contamination	Minimal	Light	Moderate	Significant	All cooling systems will scrub contaminants from the atmosphere. The likelihood of these leading to fouling will depend on the amount of dust. The potential for this to result in fouling may also be influenced by the biofouling potential which if high may provide the 'glue' which binds the dust together to form an adherent deposit. The risk of this type of fouling is probably minimal for a comfort cooling or light industrial application with good microbial control, but may be increased significantly by local building work or a nearby industrial process, which raises the atmospheric dust level
This matrix is an example of how the system operator and their specialist water treatment service provider can use the operational history to help predict the likelihood of an increase in the level of fouling in the cooling system since the last inspection/cleaning operation. Looking at a range of factors that influence whether the system is likely to have become more fouled may help determine the need for inspection and approach required to cleaning at the next shutdown. The indicators chosen are just that, requiring interpretation, and would need to be adapted to specific situations. If all the indicators are 'good' then it is highly likely that system condition will not have deteriorated significantly since the last inspection (other than the normal build-up of sediment in sumps). If that inspection concluded that the system condition was satisfactory, it may only be necessary to verify that is still the case by limited inspection. If, on the other hand, a number of indicators score a 'high risk', increased fouling is highly likely and the planned inspection and cleaning regime will need to reflect this. Where possible, a thorough baseline inspection should be carried out to establish and record the system and pack condition at the start. Where that is not possible, a matrix like this may be used to assess retrospectively the likelihood of fouling, based on prior history.						

1.86 The frequency of system inspections should be increased if the water quality deteriorates or there is an incident likely to lead to increased fouling. If inspections are infrequent, such as for a continuously operating system, then precautions need to be particularly rigorous and additional control measures may be required.

1.87 Access permitting, pre-clean inspections should look for evidence of fouling in the following areas:

- cooling tower base tank (or pond) and other system sumps;
- the cooling tower pack;
- distribution troughs or spray nozzles;
- drift eliminators.

1.88 If the cooling tower sump or pack is heavily fouled, it is probable that other parts of the system, such as heat exchangers and pipework, are also fouled and require cleaning either by physical and/or chemical means. Where possible, a more comprehensive inspection of these parts should be undertaken, eg during a shutdown. Inspections should be carried out with all the circulating water pumps and air fans switched off.

1.89 Table 1.3 provides guidance on what to inspect, how to inspect and what to look for in the various parts of the cooling system. Keep a record of any significant findings and actions.

Table 1.3 Guidance on cooling water system inspection

What to inspect	How to inspect	What to look for
General system condition	Visually inspect the accessible parts during normal operation and particularly during shutdown	Damage to protective finishes Scaling and/or corrosion Biofilm/biofouling Build-up of dirt and debris
Heat exchanger	Visually inspect the heat exchanger for degree of fouling and refer to heat transfer data, if available	Scale, corrosion or fouling
Cooling tower water distribution system	Visually inspect during shutdown – (ensure safe means of access). Poor distribution may be evident from deposition or damage to the top of the pack	Deposition in trough or nozzles Poor water distribution Physical damage and leakage
Drift eliminators	Visually inspect (ensure safe access) Where possible remove for thorough inspection	Deposits Damage Correct orientation and fitting
Cooling tower pack	Visual assessment techniques of the cooling tower pack include: ■ removal of the entire pack ■ removal of the representative sections of the pack ■ use of a boroscope to inspect representative sections of the pack either removed or in situ ■ wet weight assessment of pack sections compared to new sections ■ knock out dry sections of pack to dislodge deposits ■ split pack blocks to inspect them internally ■ visual assessment with a comprehensive written and photographic record	Correct fitting and orientation Sagging Embrittlement Deposition and fouling Evidence of poor water distribution
Fill pack supports and internal structures	Inspect these once the pack is removed or assess in another way if the pack cannot be removed, eg using a boroscope or a digital camera	Corrosion Sagging or collapse Build-up of deposits
Fill baskets and tie rods (sheet pack)	Where practical remove, otherwise inspect in situ	Corrosion or embrittlement Collapse of modules
Cooling tower base tank (or pond) and other system sumps	Visual assessment after draining, but a more limited assessment can be made by probing a sump without draining	Build-up of deposits Evidence of process contamination Biofouling

How do I interpret the findings of the inspection?

1.90 Deposits are likely to be comprised of a mixture of foulants such as scale or corrosion products, airborne dust or foreign bodies, waterborne silt from the incoming water supply, process contaminants and/or biofilm. Table 1.4 shows the significance of each type of deposit and the recommended corrective actions.

Table 1.4 The significance of and recommended actions for different types of deposit

Deposit source/ composition	**Significance**	**Recommended action**
Hardness scale	Hardness scale forms a barrier to treatment chemicals and may provide microbial habitat. Scale formation results in loss of heat transfer, reduced flow rates, loss of cooling efficiency	Where necessary, clean with appropriate process Review water treatment scale control measures For fill packs, see Table 1.5 for acceptability based on deposit thickness and surface coverage
Mud and silt or airborne dust from agriculture, industry, earthworks, building or demolition	Sediment is likely to accumulate in areas where the water velocity is low, such as the cooling tower base tank (or pond), distribution manifolds and troughs and balance lines. Sediment can provide a microbial habitat and will encourage under-deposit corrosion For fill packs, refer to Table 1.5 for acceptability based on coverage and thickness of sediment layer	Where necessary clean with appropriate process Review water treatment fouling control measures Consider increasing the frequency of cleaning and inspection Consider additional control measures such as filtration
Airborne foreign bodies and organic deposits (non-microbial), eg leaves	These can impair airflow, water flow and cooling efficiency and provide microbial nutrients	Remove as soon as practicable Review the frequency of inspection and cleaning Consider using more effective inlet shielding
Organic process contaminants, eg oil, grease	These can affect water condition severely and are likely to affect cooling efficiency They may serve as microbial nutrients, form chemical deposits and compromise water treatment programmes	Cleaning should be carried out as soon as practicable Review control measures to prevent system contamination Identify contaminant source to help determine cleaning process
Algae	Algae grow in the light, so they are unlikely to be found in the enclosed system, but they may be found on wetted areas exposed to light Algae can cause fouling and provide a nutrient source for bacteria	Clean using a suitable disinfectant/algaecide and physical cleaning Prevent light ingress if possible Review biocide regime
Biofilm	Thin deposits may be transparent but detectable by feel. Thicker deposits are often grey or light brown in colour Biofilm can impair heat transfer efficiency, cause severe localised corrosion and encourage the growth of legionella and should be considered as high-risk contamination	Disinfect and clean the system as soon as practicable Review the microbial control measures

How clean does the pack need to be?

1.91 The cooling tower pack can potentially become fouled with a wider range of deposits than the cooling tower base tank and other system sumps, and is a good indicator of the overall system cleanliness.

1.92 After a period of use, cooling tower pack is likely to become fouled and the extent and nature of the fouling will depend on a number of factors, including the chemical composition of the make-up water, the presence of process and environmental contaminants and the efficacy of the water treatment programme in place. Table 1.5 and Figures 1.5 and 1.6 suitably demonstrate the levels of organic and inorganic contamination that are acceptable and where to take action to improve cleanliness.

Table 1.5 Action levels for inorganic scale, dust and silt deposits, based on coverage and thickness on cooling tower pack

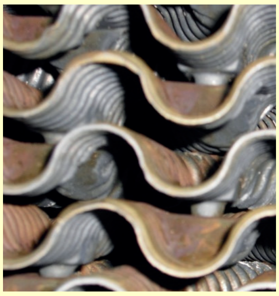
	Deposit thickness			
Surface coverage	**Eggshell**	**Up to 1 mm**	**1–3 mm**	**> 3 mm**
50%+	Acceptable	Caution	High risk	High risk
25–50%	Acceptable	Caution	High risk	High risk
10–25%	Acceptable	Acceptable	Caution	High risk
<10%	Acceptable	Acceptable	Caution	Caution
Estimate the proportion of pack surface that is covered with deposits and its thickness. If the material appears to be non-biological, anything no thicker than an eggshell can be considered to be an insignificant stain and not a deposit. If the contaminating material appears to be microbial, ie biofilm, irrespective of thickness, the pack should be cleaned. Deposits may be unevenly distributed within the pack, but the dirtiest areas should be used for classification of the deposit thickness. Compare the extent of the deposits with previous inspections to determine whether fouling is increasing.				

Figure 1.5 Cooling tower pack photographs

Good: Pack very clean – no action required

Staining and not a deposit

Acceptable: Light mineral deposits only – monitor for deterioration



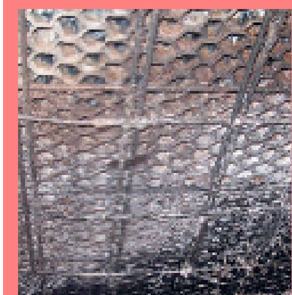
Caution: Deposits more significant or may be biological – action required

Review scale control measures and monitor for deterioration

Review scale control measures and monitor for deterioration

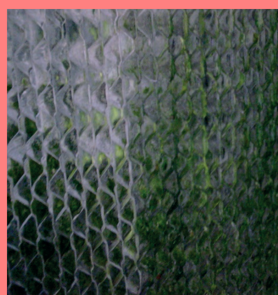
Deposit may be biofouling. Further investigation is required

High risk: Heavy mineral or microbial deposits – urgent action required



Heavy scale

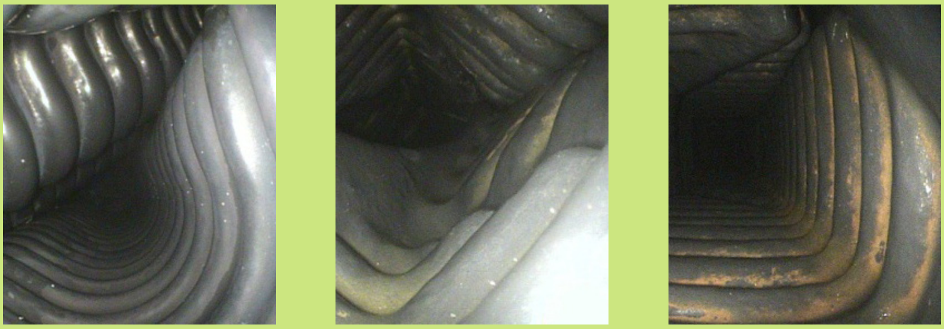
Silt



Algal growth

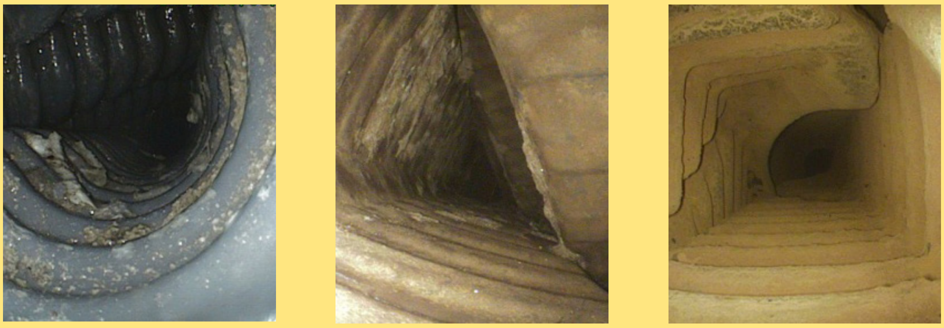
Figure 1.6 Cooling tower pack boroscope pictures

Good: Pack clean – no action required



Acceptable: Light mineral deposits only – monitor for deterioration

Caution: Deposits more significant or may be biological – action required



Deposit may be biofouling. Further investigation is required	Review scale control measures and monitor for deterioration	Review scale control measures and monitor for deterioration

High risk: Heavy mineral or microbial deposits – urgent action required

Cleaning and disinfection procedure

1.93 A cooling system cleaning operation will normally comprise a pre-cleaning disinfection (if needed); physical cleaning and, if appropriate, chemical cleaning; and a post-cleaning disinfection.

Pre-cleaning disinfection

1.94 Before cleaning the system, water should be disinfected using an oxidising biocide such as chlorine, bromine or chlorine dioxide in conjunction with a suitable bio-dispersant. This is to minimise health risks to the cleaning staff.

1.95 The required concentration of the free disinfectant should be established and circulated throughout the cooling system for an initial period with the fans off to ensure thorough mixing of the disinfectant throughout the system. Once this is achieved, the fan(s) should be switched on for the remainder of the process to ensure that disinfectant reaches all internal surfaces that become wet during normal operation of the tower and which potentially could be contaminated.

1.96 The disinfecting solution is to be monitored periodically and maintained in the cooling system throughout the disinfection period by adding more disinfectant as required. The normal disinfectant level required depends on the minimum circulation period adopted. A continuous minimum residual of 5 mg/l as free chlorine, for a minimum period of 5 hours, should be maintained, but if time available to conduct the operation is limited, using a higher disinfectant concentration for a shorter time may be acceptable. This will, however, increase the risk of damage to the fabric of the system. Excessive disinfectant levels should be avoided and Table 1.6 provides the minimum contact times and disinfectant levels.

Table 1.6 Required minimum disinfectant level for different circulation times

Minimum circulation time	Minimum continuous disinfectant level (as free Cl_2)
5 hours	5 mg/l
2 hours	25 mg/l
1 hour	50 mg/l

1.97 The required residual needs to be established throughout the whole system for the contact time and not simply the cooling tower sump. Systems with multiple sumps may require dosing at each sump to ensure good distribution of disinfectant.

1.98 If chlorine is used as the disinfectant, its efficacy is reduced if the system pH value is greater than pH 8. To achieve the same disinfection effect, its residual needs to be increased 3–4 times, ie in place of 5 mg/l for 5 hours 15–20 mg/l is required for the same period. Generally, this is not recommended, so if the system water is above pH 8 adopt one of the following procedures to compensate, without increasing the chlorine residual:

- introduce a heavy bleed-off for several hours to both reduce the pH of the system water and its chlorine demand before carrying out disinfection;
- reduce system pH by adding an acid;
- augment chlorine dosage with sufficient sodium bromide to change the disinfectant from chlorine to bromine.

1.99 If bromine or chlorine dioxide is used in systems where the pH is above 8, the reserves do not need to be increased or the pH adjusted, as these disinfectants remain effective at higher pH.

1.100 Once the system has been pre-disinfected, the water should then be de-chlorinated and drained. Pre-cleaning disinfection may not be needed if:

- the system is normally continuously automatically dosed with an oxidising biocide and bio-dispersant; and
- the control of the microbial activity and biocide residual has been consistently achieved since the previous cleaning operation (ie continuous minimum free chlorine residuals of 0.5–1 mg/l or bromine residuals of 1–2 mg/l and bacterial levels of less than 1x104 cfu/ml or less).

1.101 A pre-disinfection should be carried out if there is any doubt about the control of the microbial activity or the oxidising biocide residual, or there is a delay between the system being shut down and the cleaning operation starting.

Cleaning

1.102 After pre-cleaning disinfection, manual cleaning operations can be carried out with all accessible areas of the tower etc being cleaned. Accessible areas of the system should be washed adequately but cleaning methods that create excessive spray, eg high pressure water jetting, should be avoided.

1.103 If considered necessary, high pressure jetting should only be carried out when the buildings nearby are unoccupied or, in the case of permanently occupied nearby buildings, windows should be closed, air inlets blanked off and the area that is being water jetted should be tented. The area should be isolated and you should consider other occupied premises nearby, as well as people who may be nearby during cleaning.

1.104 Cleaning staff that carry out water jetting, or other operations which could create aerosols, should wear suitable respiratory protective equipment (RPE), and the cleaning contractor in the method statement should specify this. For example, this could be RPE fitted with filters that will ensure aerosols created are not inhaled. Staff using this equipment should be adequately trained and the equipment properly maintained. Further guidance on why and when RPE should be used and how to select RPE that is adequate and suitable is available in HSG53 *Respiratory protective equipment at work: A practical guide*.[12]

1.105 In addition to manual cleaning operations, enhanced chemical cleaning processes may be required to remove certain types of deposit. Table 1.7 gives guidance on cleaning processes that can be employed for different types of fouling. Once cleaned, the system should be sluiced out until the water going to drain is clear.

Table 1.7 Cleaning processes for different types of fouling

Predominant type of fouling	**Cleaning procedure**
Silt, sediment and airborne dust (predominantly inorganic)	Physical removal with a 'wet vac' or similar. Post-disinfect to ensure any microbial fouling released is killed. If heavy fouling of this type is 'normal' for the system, consider fitting side-stream filtration
Biofouling	Strong oxidising biocide combined with bio-dispersant and circulated with fans off and heavy purge. Shut system down and drain all sumps, check cleanliness of strainers, heat exchangers and pack. Review ongoing biocide regime
Hardness scale	Acid clean using appropriate acid and inhibitor. If cleaning proves to be ineffective, consideration should be given to replacing heavily scaled pack. Review water treatment programme for scale control
Corrosion products	Acid clean using appropriate acid and inhibitor or suitable chelant/ dispersant. Review water treatment programme for corrosion control
Organic process contaminants	Identify the contaminant and select an appropriate solvent/ dispersant. Consideration should be given to modifying the cooling system to reduce or prevent contamination of the cooling system water with process material

Cleaning of the cooling tower pack

1.106 Maintaining the cleanliness of the cooling system and the water in it is critical to prevent or control the risk of exposure to legionella; it is therefore necessary to demonstrate the cleanliness of the system including the pack, whether the pack is removed or not. The approach to cleaning the cooling tower pack will depend on a number of factors, including:

- the nature of the contamination;
- the design of the cooling tower and practicalities of accessing and/or removing the pack;
- the type of pack in use, ie block or sheet.

1.107 If a cooling system operates in a relatively clean environment with continuous effective water treatment, it is possible for a cooling tower pack to remain free from fouling for many years. However, a pack may appear clean from the visible surfaces but be fouled internally.

1.108 Removal of the cooling tower pack, where this can be done relatively easily and reinstated safely without damage, will inform the inspection and assessment and aid any potential cleaning. However, whether the pack is removed or not, evidence of its cleanliness should be demonstrated, an assessment made using appropriate techniques as detailed in Table 1.3. and the findings recorded. Photographic records of pack condition can help in this process and should be maintained.

1.109 Sheet pack can also be separated to allow silt or sediment to be washed off. Block-type pack cannot be cleaned effectively by jetting but may respond to flushing with high volumes of water or cleaning fluid. If a chemical process is required to remove fouling, this may be most conveniently done in situ by circulating a concentrated cleaning solution through the pack. Application of a suitable cleaning solution formulated as a foam may remove light deposits in situ. Alternatively, the pack can be removed and immersed in a suitable cleaning solution ex situ. In some circumstances it may be possible to remove certain deposits by removing the pack, allowing it to dry out and then gently knocking or dropping it from a low height to shock the dried deposits off, taking care not to damage the pack itself.

1.110 Where the pack or drift eliminators are heavily fouled and cleaning is not practical, consider replacing them and it may be prudent to hold sections of new pack and drift eliminators on site for use during system cleaning operations. It is important that replacement pack and drift eliminator match or have the same dimensions and performance as the original, as this may impact on the amount of aerosol released from the system.

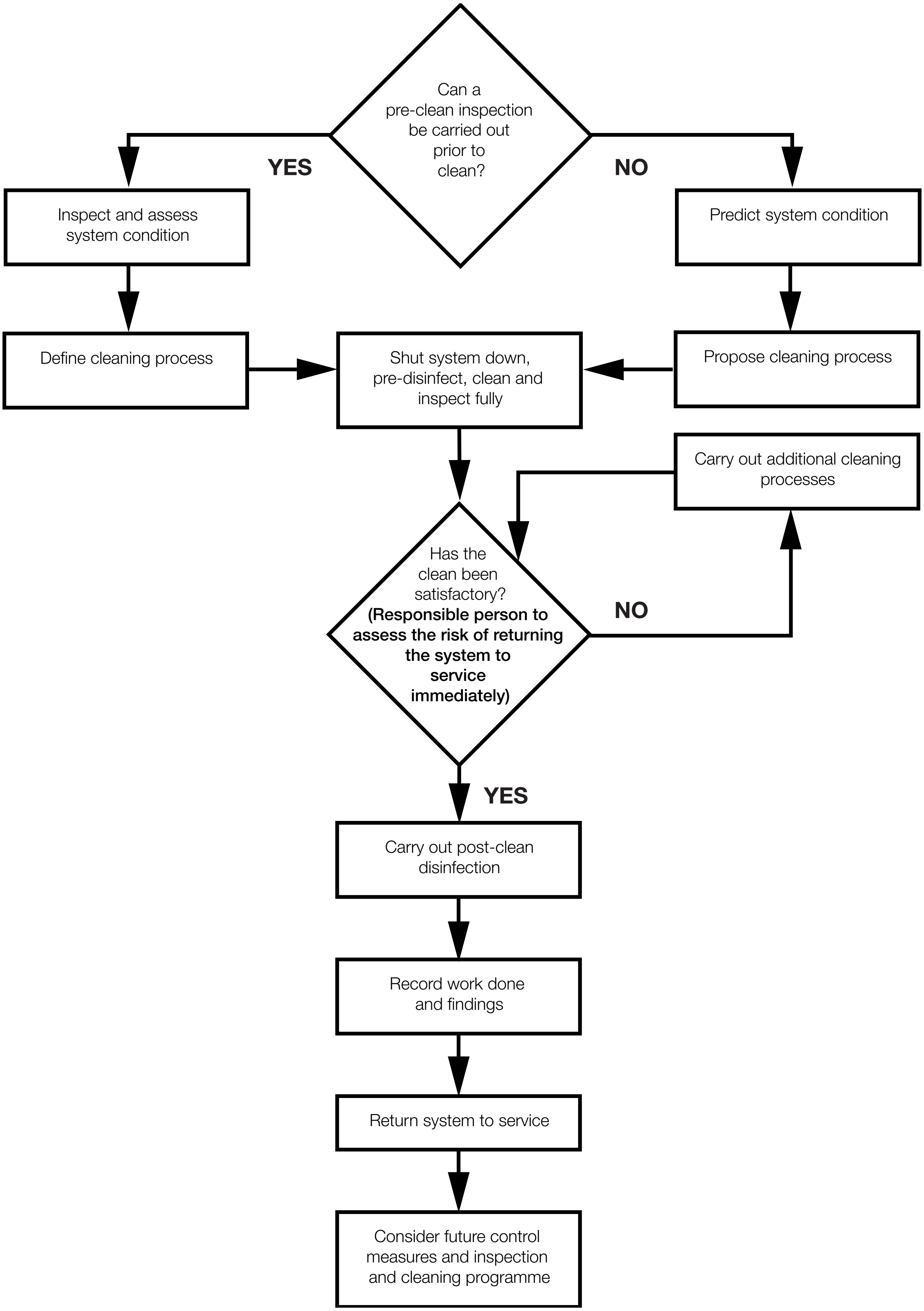
Post-cleaning disinfection

1.111 On completing the cleaning operation, the system should be refilled and disinfected using the method described under 'pre-cleaning disinfection', using an oxidising biocide to maintain the minimum disinfectant levels and circulation times indicated in Table 1.6. The disinfectant level should be monitored periodically and topped up if necessary to ensure that the minimum levels are maintained. The use of a bio-dispersant will enhance the effectiveness of this disinfection.

1.112 If returning the system to immediate service, the disinfectant level can be allowed to decay over the first few hours of operation and a start-up level of the normal water treatment chemicals added. If, however, the system is going to be left idle before restarting, dechlorinate the water, drain and flush the system and leave it empty. On start-up, the system should be refilled with fresh water and the water treatment programme immediately reinstated with a dosage of the appropriate start-up level of treatment chemicals, including biocides.

1.113 Before water containing high residuals of chlorine, bromine, chlorine dioxide etc is discharged to drain, neutralise the disinfectant. The usual procedure is to add sodium thiosulphate, sodium sulphite or sodium bisulphite as a neutraliser. The effluent from any disinfection and/or chemical cleaning process, neutralised or not, may be regarded by the effluent receiver as trade effluent and may require a 'consent to discharge'. Therefore, permission to discharge may be required from the effluent receiver.

Figure 1.7 Flowchart of inspection and cleaning decision-making process



Monitoring water quality and understanding water treatment analytical reports

1.114 The risk from exposure to legionella should be prevented or controlled and the precautions taken monitored to ensure that they remain effective. This section gives guidance on how to monitor water quality in cooling systems.

The need for monitoring and analysis

1.115 The composition of make-up and cooling waters should be routinely analysed to ensure the continued effectiveness and suitability of the treatment programme. There may be more than one source of make-up water. Analyse each one and calculate its contribution to the total make-up. The frequency and extent of any analysis will depend on the operating characteristics of the system. The typical frequency is once a week to ensure that chemical dosage and system water bleed rates are correct. Table 1.8 gives the typical on-site monitoring and analytical checks for water cooling treatment and these can be carried out by the competent site personnel or by a water treatment company.

1.116 The identification of changes in the water chemistry such as pH, dissolved and suspended solids, hardness, chloride and alkalinity should allow any necessary corrective actions to be taken to the treatment programme or system operating conditions. In addition, levels of treatment chemicals should be measured such as scale and corrosion inhibitors and oxidising biocides. Circulating levels of non-oxidising biocides may be difficult to measure but the quantity added to the systems should be checked and recorded weekly. Monitoring corrosion rates may also be appropriate.

1.117 The tests referred to in Table 1.8 should be provided in the form of a report, in either hard copy or electronic format and will form part of the record-keeping requirements. Figure 1.8 gives an example of a report (often referred to as the Water Treatment Service Report). It is important that the responsible person and their water treatment provider fully discuss the report and agree any necessary actions to ensure ongoing control is maintained.

1.118 The monitoring programme should also include the routine sampling and testing for the presence of bacteria, both general (aerobic) bacterial species and legionella bacteria. Since the detection of legionella bacteria requires specialist laboratory techniques, routine monitoring for aerobic bacteria is used as an indication of whether microbiological control is being achieved.

1.119 The most common method of measuring microbial activity within a cooling system is using dip slides. These are commercially available plastic slides, which are coated with sterile nutrient agar – a medium on which many microorganisms will grow, but not legionella. Bacteria in the cooling water will grow on the agar and form visible colonies. Comparison with a chart will indicate the number of bacteria in the water, expressed as colony forming units per millilitre (cfu/ml).

Table 1.8 Typical on-site monitoring and analytical checks for cooling water treatment

Parameter* (and normal units)	**Make-up water analysis frequency**	**Cooling water analysis frequency**
Calcium or total hardness (as mg/l $CaCO_3$)	Monthly	Monthly
Total alkalinity (as mg/l $CaCO_3$)	Quarterly	Monthly
Conductivity (µS/cm) or TDS (mg/l)	Monthly	Weekly
pH	Quarterly	Weekly
Inhibitor(s) level (mg/l)	N/A	Monthly
Oxidising biocide (mg/l)	N/A	Weekly
Microbial activity (cfu/ml)	Quarterly	Weekly
Legionella analysis	N/A	Quarterly
Total iron (mg/l Fe)	Quarterly	Monthly
Chloride (mg/l Cl)	Monthly	Monthly
Concentration factor (calculated value)	N/A	Monthly
Calcium balance (calculated value)	N/A	Monthly
*An explanation of the terms used in the 'parameter' column is provided in Info Box 1.6. These parameters are typically required to check that the correct level of each treatment chemical is applied and that adequate control is maintained over scaling, corrosion and microbial activity. They are not universally applicable and tests may be omitted or added to, as appropriate, for the specific cooling system, make-up and system water character and the water treatment techniques employed.		

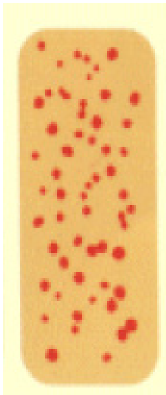
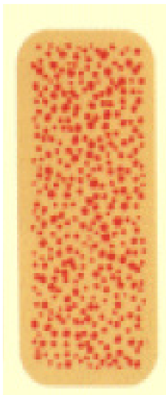
1.120 Dip slides should be used to sample the system water downstream of the heat source. The water sample is usually taken from the return line to the tower. If a sample point is used, it is important to flush it to ensure a representative sample before the slide is dipped. The dip slide should be placed into its sterile container and into an incubator for a minimum of 48 hours, usually set at 30 °C. The incubation period and the temperature should be the same each time the test is performed.

1.121 Cooling system water should be tested weekly, using dip slides (or similar). The timing of dip slides and other microbial sampling is important. The sampling point should be remote from the biocide dosing point and for biocides, which are applied in a shot dose, sampling should be taken when the residual biocide is at its lowest and ideally performed at the same time each week. Table 1.9 lists guide values for the general microbial activity and the appropriate action to take.

1.122 While the number of microorganisms is itself important, it is also necessary to monitor any changes from week to week, particularly if there are any increases in the numbers of microorganisms detected. This should always result in a review of the system and the control strategies. A graphical representation of these data will often help to monitor any trends.

1.123 If the control strategy is effective, the dip slide counts should reflect a system under control. If an unusually high result is obtained, the test should be repeated immediately and, if confirmed, appropriate action taken. Consistently high microbial counts using dip slides should be checked by laboratory-based TVCs. The laboratory performing the tests should be accredited by the United Kingdom Accreditation Service (UKAS), see 'Further sources of information'.

Table 1.9 Comments and action levels in response to general microbial counts, eg dip slide results

AEROBIC COUNT cfu/ml and dip slide appearance at 30 °C for 48 hours incubation	**COMMENTS AND ACTION REQUIRED**
Less than 10 000 (1×10^4) cfu/ml  (Diagram here shows dip slide indicating 1×10^4 cfu/ml)	**System under control: Good general microbial control and no action required**
More than 10 000 (1×10^4) cfu/ml and up to 100 000 (1×10^5) cfu/ml	**Caution: Review programme operation** Ensure the water treatment programme and system operation is operating correctly. Adjust the biocide dosage if appropriate and resample after 24 hours
More than 100 000 (1×10^5) cfu/ml  (Diagram here shows dip slide 1×10^5 cfu/ml or greater)	**Action: Review programme operation and implement corrective action** As a precaution, the system should be shot dosed with an appropriate biocide or the level of continuous dosage of biocide should be increased. The system should then be resampled after 24 hours to determine the effectiveness of the corrective action. If the high count persists, the control programme should be reviewed to identify any necessary remedial actions

1.124 Alternative techniques for determining microbial activity have been developed for on-site use. It is important that the data from such tests can be properly interpreted, so that appropriate action levels can be set to enable informed decisions on the control measures needed. This may be achieved by running the tests in parallel with traditional culture-based methods, such as dip slides, for a period.

Monitoring for legionella

1.125 Routine monitoring, specifically for the presence of legionella, should be undertaken at least quarterly. Table 1.10 gives guidance on the interpretation of legionella results and recommended actions.

1.126 More frequent sampling may be necessary for other reasons, such as:

- to help identify possible sources of the bacteria during outbreaks of legionnaires' disease;
- when commissioning a system and establishing a new or modified treatment programme – for which sampling should initially be carried out weekly and the frequency reviewed when it can be shown that the system is under control;
- if a legionella-positive sample is found, more frequent samples may be required as part of the review of the system risk assessment, to help establish the source of the contamination and when the system is back under control (see Table 1.10);
- the risk assessment indicates more frequent sampling is required, eg close vicinity of susceptible populations.

1.127 The sampling method should be in accordance with BS 7592:2008 *Sampling for Legionella bacteria in water systems*. *Code of practice*[13] and the biocide neutralised where possible. Neutralisation can be difficult when non-oxidising biocides are in use. It is important that samples reach the laboratory without delay, and that laboratory staff are informed of whether neutralisation has been possible or active biocide is likely to remain in the sample. As non-oxidising biocides are applied in shot dosages, where possible, the water sample should be taken immediately before an application of biocide to minimise the impact of the biocide on the test result.

1.128 Samples should be taken from the circulating water system near to and downstream of the heat source. They should be tested by a laboratory accredited through UKAS to EN ISO 17025:2005 *General requirements for the competence of testing and calibration laboratories*.[14] Testing for legionella by culture should be done in accordance with BS 6068-4.12:1998/ISO 11731:1998 *Water quality. Microbiological methods. Detection and enumeration of Legionella*.[15] The laboratory should also apply a minimum theoretical mathematical detection limit which is usually that of less than, or equal to, 100 legionella per litre of sample for culture-based methods.

1.129 Legionella are commonly found in almost all natural water sources, albeit in low numbers, so sampling of water systems and services may often yield positive results and the interpretation of the results of any case of sampling should be carried out by experienced microbiologists. Failure to detect legionella should not lead to relaxation of control measures and monitoring. Neither should monitoring for the presence of legionella in a cooling system be used as a substitute in any way for vigilance with control strategies and those measures identified in the risk assessment.

Table 1.10 Comments and action levels in response to legionella analysis results

Legionella cfu/litre	Comments and action required
Not detected or up to 100	'Not detected' does not mean 'not present' or that there is no risk. Focus on maintaining control measures, particularly keeping the general aerobic count (Table 1.9) less than 1×10^4 cfu/ml
>100 and up to 1000	Low-level legionella count detected. This may be a sporadic result or could indicate a persistent problem (Table 1.2). Reassess the control programme and the general aerobic count (Table 1.9). Ensure the water treatment system is operating correctly. Adjust the biocide dosage if the general aerobic count does not indicate good control (less than 1×10^4 cfu/ml). Resample to verify the initial result and then again to check that remedial actions are effective
>1000 or persistent low-level results	Immediate action required. Resample and as a precautionary measure shot dose the water system with an appropriate biocide or increase the level of continuous dosage of biocide. Reassess the entire control programme and take any corrective actions. Resample the system to verify the count and to determine the effectiveness of the corrective action, resample again within 48 hours. If the high legionella counts persist, review the risk assessment to identify further remedial actions
Once the water system is colonised with legionella, it may prove extremely difficult to reduce numbers to undetectable levels and periodic positive legionella results may recur. Under such circumstances steps should be taken to make sure the risk assessment reflects this and control measures should be devised to ensure that, although likely to be present at low levels, legionella cannot multiply to dangerous levels	

Info box 1.6: Key terms used in a water treatment service report

It is convention to express hardness and alkalinity results as 'mg/l $CaCO_3$' (calcium carbonate) to simplify comparison and conversion between the parameters. Other component parameters of the water are expressed simply as mg/l or ppm (parts per million).

Total hardness is the sum of calcium and magnesium hardness, which if inadequately controlled will lead to scale formation.

Calcium hardness strongly influences the scaling and corrosive tendencies of the water.

M alkalinity (sometimes called total alkalinity) influences the scaling and corrosive tendencies of the water.

pH influences scaling and corrosive tendencies and the performance of both biocides and inhibitors.

Conductivity is an indicator of the overall mineral content of the water and its value is often used to set the cooling system bleed level.

Chloride is a corrosive ion, which may need to be limited depending on the system metallurgy**.** Chloride levels can be used to measure concentration factors and may indicate brine loss from a malfunctioning water softener where fitted**.**

Iron and copper Elevated levels may indicate increased corrosion rates. Soluble iron in the circulating water can promote the growth of legionella in the system.

Concentration factor (also known as cycles of concentration). This is a measurement of the increase in the mineral content of the cooling water compared to the make-up water. Concentration factors can be calculated by comparing parameters such as conductivity, TDS (Total Dissolved Solids), magnesium hardness, chloride and silica in the cooling water system with the respective levels in the make-up water. Concentration factor is a primary parameter set by the water treatment company as a basis for controlling the treatment programme. A concentration factor below the control level is wasteful of energy, water and chemicals, while a high concentration factor may lead to accelerated corrosion, scale deposition or fouling.

Calcium balance (also known as calcium recovery) is a comparison between the overall concentration factor in the system and the calcium-specific concentration factor. The equation used is (calcium in the system water)/(calcium in the make-up x the overall concentration factor). It can be expressed as a decimal or a percentage. A decimal less than 0.9 (or <90%) may indicate an increased likelihood of scale formation.

Inhibitor A chemical additive that minimises the rate of corrosion or the amount of hardness precipitation, or both. Dosing levels will be set by the water treatment company based on the water chemistry of the system.

Free chlorine (or bromine) Halogens such as chlorine or bromine are used as biocides and disinfectants and are known as oxidising biocides. They are dosed to achieve free reserves, typically 0.5–1.0 mg/l for chlorine and 1.0–2.0 mg/l for bromine. Efficacy is compromised at higher pH levels. Chlorine (or bromine) may be dosed continuously or as shot dosages. Application rates can be controlled automatically by feedback from an appropriate in-line analyser.

Microbial activity is usually measured by dip slide, where the result is expressed as colony forming units per millilitre (cfu/ml). Dip slides should be incubated at 30 °C and read after 48 hours. An alternative rapid monitoring technique using ATP/bioluminescence may also be used. Results are expressed as relative light units (RLU). The water treatment company must demonstrate that the target RLU level is comparable with target cfu/ml levels.

Redox potential or oxidation-reduction potential (ORP), expressed in mV. The presence of oxidising biocides in water affects an electrical characteristic called the redox potential or ORP and this can be used to control dosage of the biocide.

Bleed (sometimes called blow-down) is the portion of system water drained to waste and replaced with fresh make-up water to control the build-up of minerals in the circulating water. System demand influences bleed rate, eg by actuating a solenoid valve via a conductivity sensor.

Suspended solids (SS), expressed as mg/l are fine solid particles in the water, either formed from water itself (hardness salts and corrosion products) or from the local environment (airborne dust, insects etc).

Figure 1.8 Typical cooling water service report

COMPANY NAME AND SITE					REPORTED TO			
					COPY TO			
SYSTEM					DATE			
ANALYSIS	RAW WATER		TREATED WATER		MAKE-UP WATER		SYSTEM WATER	
Total hardness mg/l $CaCO_3$								
Calcium hardness mg/l $CaCO_3$								
Magnesium hardness mg/l $CaCO_3$								
M Alkalinity mg/l $CaCO_3$								
P Alkalinity mg/l $CaCO_3$								
Chloride mg/l Cl								
Conductivity µS/cm								
pH								
Copper mg/l Cu								
Iron mg/l Fe								
Concentration factor								
Calcium balance								
Inhibitor mg/l product								
Redox potential mV								
Bromine mg/l Br_2 or mg/l Cl_2								
Dip slides (date taken)								
COMMENTS AND RECOMMENDATIONS								
LAST VISIT MADE (date)					CLIENT (Name and signature)			
NEXT VISIT DUE (date)					SERVICE PROVIDER (Name and signature)			
DOSING CONTROL			PRESENT		FUTURE		STOCK LEVEL	
	Chemical A		Present pump setting		New pump setting		…kg	
	Chemical B		Present pump setting		New pump setting		…kg	
	Chemical C		Present pump setting		New pump setting		…kg	
	Bleed		Present setting		New setting		N/A	
	Auto control		Site unit setting		Provider's unit reading		N/A	
	etc…		etc…		etc…		etc…	

Appendix 1 Legionella risk assessment

1 It is a legal duty to carry out an assessment to identify and assess whether there is a risk posed by exposure to legionella from operating the cooling system or any work associated with it.

2 The risk assessment should consider all aspects of operation of the cooling system and should be specific to the individual system under review. Consult site personnel who manage the systems to determine current operational practice. The commissioning, decommissioning, periods of operation, maintenance, treatment and subsequent management of each individual aspect of operation will require review and validation to ensure site procedures are effective.

3 The list below shows the most common key requirements when assessing risk associated with a cooling system based on mechanical, operational, chemical and management aspects:

- Details of management personnel who play an active role in the risk management process, including names, job titles and contact information for:
  - the statutory dutyholder;
  - the appointed responsible person(s), including deputies;
  - service providers, eg risk assessors, water treatment suppliers, cleaning and disinfection service providers.
- An assessment of the competence of those associated with risk management, including their training records.
- Identification of roles and responsibilities, including employees, contractors and consultants.
- A check that you have considered removing the risk by ‘substitution or elimination’.
- The scope of the assessment, ie the details and entirety of the plant being assessed.
- Details of the availability of an up-to-date schematic diagram, including all parts of the system where water may be used or stored.
- Details of the design of the cooling system, including asset details and:
  - the location of any cooling towers, evaporative condensers and/or dry/wet cooling systems;
  - the type of cooling towers, evaporative condensers and/or dry/wet cooling systems;
  - the construction materials;
  - the pipework system;
  - details of system modifications;
  - details on safe access relating to parts of the cooling system.
- Assessment of the potential for the system to become contaminated with legionella and other material, including consideration of:
  - the source and quality of the make-up water;
  - the likelihood for airborne contamination.
- Details of any water pre-treatment process such as filtration, softening, particularly:
  - maintenance;
  - effectiveness;
  - monitoring.
- Assessment of the potential for legionella to grow in the system, including a review of:
  - normal plant operating characteristics and periods of intermittent use;

  - areas of low water flow or possible stagnation (eg deadlegs);
  - possible process contamination;
  - water temperatures that promote growth;
  - effectiveness of control measures, including chemical and physical water treatment measures, disinfection and cleaning regimes and remedial work and maintenance.
- Assessment of the risk of legionella being released in an aerosol, including potential for spray or splashes escaping from the system from the cooling tower, process or associated operations during normal or abnormal use.
- Assessment of the risk of people being exposed to the aerosol due to the:
  - location of equipment;
  - numbers of people likely to be exposed;
  - likely susceptibility of exposed populations.
- A review of the legionella control scheme, including:
  - management procedures for each stage of operation;
  - site records or log books, including system maintenance records; routine monitoring data; water treatment service reports; cleaning and disinfection records; legionella and other microbial analysis results;
  - evidence of corrective actions being implemented (eg defect/action process);
  - evidence of proactive management and follow-up of previous assessment recommendations or identified remedial actions;
  - evidence of the competence of those involved in control and monitoring activities.

4 The assessment should include recommendations for remedial actions for the control of legionella where necessary and identify who will undertake such actions. Prioritise actions and set a review date for determining completion of these tasks.

5 Further detailed information is available in BS 8580: 2010 *Water quality. Risk assessment for Legionella control. Code of Practice* and the Water Management Society's *Guide to risk assessment for water services*.

Appendix 2 Legionella written control scheme

1 The risk from exposure will normally be controlled by measures which do not allow the proliferation of legionella bacteria in the system. Once the risk is identified and assessed, a written control scheme should be prepared, implemented and properly managed.

2 The scheme should specify the various control measures and how to use and carry out those measures. It should also describe the water treatment regimes and the correct operation of the water system plant. The scheme should be specific and relate to the cooling plant being operated on site, ie tailored to the cooling plant covered by the risk assessment. Along with the information contained in this guidance, the following list summarises the information to include in a written control scheme.

- Purpose.
- Scope.
- Risk assessment.
- Notification of cooling towers.
- Management structure:
  - dutyholder;
  - responsible person(s) and communication pathways;
  - training;
  - allocation of responsibilities.
- Up-to-date schematic diagram showing layout of the cooling system(s).
- The correct and safe operation of the system.
- Precautions in place to prevent or minimise risk associated with cooling systems.
- Analytical tests, other operational checks, inspections and calibrations to be carried out, their frequency and any resulting corrective actions.
- Remedial action to be taken in the event that the scheme is shown not to be effective, including control scheme reviews and any modifications made.
- Health and safety information, including details on storage, handling, use and disposal of any disinfectant used in both the treatment of the system and testing of the system water.
- Incident plan which covers, eg:
  - very high microbial activity as estimated by dip slides or TVCs, count or repeat positive water analyses for *Legionella spp*;
  - an outbreak of legionellosis, suspected or confirmed as being centred at the site;
  - an outbreak of legionellosis, the exact source of which has yet to be confirmed, but which is believed to be centred in an area which includes the site.

Appendix 3 Action in the event of an outbreak of legionellosis

1 In England and Wales, legionnaires' disease is notifiable under the Health Protection (Notification) Regulations 2010[16] and in Scotland under the Public Health (Notification of Infectious Diseases) (Scotland) Regulations 1988.[17] Under these Regulations, human diagnostic laboratories must notify Public Health England (PHE), Public Health Wales (PHW) or Health Protection Scotland (HPS) (see 'Further sources of advice') of microbiologically confirmed cases of legionnaires' disease.

2 An outbreak is defined as two or more cases where the onset of illness is closely linked in time (weeks rather than months) and where there is epidemiological evidence of a common source of infection, with or without microbiological evidence. An incident/outbreak control team should always be convened to investigate outbreaks. It is the responsibility of the Proper Officer to declare an outbreak. The Proper Officer, appointed by the local authority, is usually a Consultant in Communicable Diseases Control (CCDC) in England and Wales, or the Consultant in Public Health Medicine (CPHM) in Scotland. If there are suspected cases of the disease, medical practitioners must notify the Proper Officer in the relevant local authority.

3 Local authorities will have jointly established incident plans to investigate major outbreaks of infectious diseases, including legionellosis, and it is the Proper Officer who activates these and invokes an Outbreak Committee, whose primary purpose is to protect public health and prevent further infection.

4 HSE or local environmental health officers (EHOs) may be involved in the investigation of outbreaks, their aim being to pursue compliance with health and safety legislation. The local authority, Proper Officer or EHO acting on their behalf will make a visit, often with the relevant officer from the enforcing authorities (ie HSE or the local authority). Any infringements of relevant legislation may be subject to a formal investigation by the appropriate enforcing authority.

5 There are published guidelines (by PHE, PHW and HPS) for the investigation and management of incidents, clusters, and outbreaks of legionnaires' disease in the community. These are, for England and Wales, *Guidance on the Control and Prevention of Legionnaires' Disease in England*[18] and for Scotland, *Guidelines on Management of Legionella Incidents, Outbreaks and Clusters in the Community*.[19]

6 If a cooling water system has been implicated in an outbreak of legionnaires' disease, emergency disinfection and cleaning of that system must take place as soon as possible, in accordance with the site incident plan.

Glossary

adiabatic cooler/condenser a term used to describe a heat rejection device that normally operates in dry mode but which can also operate using evaporative cooling to pre-cool the air stream with water, to increase the device's cooling capacity when ambient air temperatures are high, eg in the summer months.

aerosol a suspension in a gaseous medium of solid particles, liquid particles or solid and liquid particles having negligible falling velocity. In the context of this document, it is a suspension of particles which may contain legionella with a typical droplet size of <5µm that can be inhaled deep into the lungs.

air conditioning a form of air treatment whereby temperature, humidity, ventilation and air cleanliness are controlled within limits determined by the requirements of the air-conditioned enclosure.

acid a chemical that reduces the pH of water and reacts with alkali or base, commonly used for removing scale and other deposits from systems and sometimes used as a scale inhibitor.

algae simple organisms similar to plants that require light for growth, typically found in aquatic environments.

alkali a chemical that increases the pH of water and reacts with an acid.

alkalinity the concentration of alkali in water (measured by titration with standard acid solution).

antibodies substances in the blood that destroy or neutralise toxins or components of bacteria known generally as antigens; and are formed as a result of the introduction into the body of the antigen to which they are antagonistic.

adenosine triphosphate (ATP) a chemical used as an energy source in cells for metabolic purposes. Its concentration in water can be used to estimate microbial population density.

bacterium (plural bacteria) a microscopic, unicellular prokaryotic organism, without a nuclear membrane.

balance pipes pipe(s) between adjoining duty towers and between duty and standby towers.

biocide a substance that kills microorganisms.

biofilm a community of microorganisms of different types growing together on a surface so that they form a slime layer.

bleed a deliberate intermittent or continuous discharge of system water to drain to allow the admission of make-up water to the system, thereby controlling the concentration of dissolved or suspended solids in the water.

blow-down another term for bleed.

bromine an element very similar to chlorine used as a biocide and sometimes as a disinfectant. The main practical difference between bromine and chlorine when used as a biocide is that bromine remains effective at higher pH levels.

chlorinate to add chlorine to water, usually in the form of a hypochlorite.

chlorine an element used as a biocide and for disinfection (see **bromine**, **combined chlorine** and **free chlorine**).

combined chlorine the amount of chlorine that has reacted with nitrogenous or organic materials to form chlorine compounds. If the materials are nitrogenous then the compounds formed are chloramines.

concentration factor compares the level of dissolved solids in the cooling water with that dissolved in the make-up water (also known as cycles of concentration or concentration ratio). Usually determined by comparison of either the chloride or magnesium concentration.

conductivity the capacity of the ions in the water to carry electrical current. Conductivity measurement is used to estimate the Total Dissolved Solids (TDS) in the water. The results are expressed as microsiemens/cm (µS/cm) and are temperature dependent. TDS can be calculated by multiplying the conductivity level with a conversion factor of 0.7. Care should be taken not to confuse conductivity and TDS figures (see **TDS**).

conductivity controller a device that measures the electrical conductivity of water and helps control it to a pre-set value.

cooling water system a heat exchange system comprising a heat-rejection plant and interconnecting recirculating water pipework (with associated pumps, valves and controls).

corrosion coupons small strips of various types of metal, placed in racks in water circuits, that can easily be removed, weighed and/or inspected to enable the corrosion characteristics of the water to be assessed.

corrosion inhibitors chemicals designed to prevent or slow down the waterside corrosion of metals.

culture the technique of detecting and enumerating bacteria by growing on an artificial medium such as agar.

DPD No 1 an indicator used in the colorimetric determination of the concentration of oxidising biocides. DPD No 1 reacts to the presence of strong biocidal species, including free chlorine and total bromine (free and combined).

deadleg a length of water system pipework leading to a fitting through which water only passes when there is draw off from the fitting, thereby providing the potential for stagnation.

dip slide coated plastic slide on which microorganisms can be grown, examined and quantified. They provide a broad indication of microbial growth only.

disinfection the reduction of the number of microorganisms to safe levels by either chemical or non-chemical means (eg biocides, heat or radiation).

dispersant a chemical that loosens organic material, such as biofilm, adhering to surfaces.

drift water droplets and aerosols entrained in the air that discharges from a cooling tower or evaporative condenser. NB The visible plume often seen above cooling towers under cool conditions is likely to be condensing water vapour (evaporated in the cooling process) rather than system water droplets/aerosol carried over.

drift eliminator equipment containing a complex system of baffles designed to minimise drift (see **drift**) discharging from a cooling tower or evaporative condenser.

evaporative cooling the process of evaporating part of a liquid which removes the necessary latent heat of evaporation from the main bulk of the liquid, cooling it.

free chlorine the amount of chlorine available to act as a disinfectant in water. Note that disinfection properties are strongly affected by the pH of the water and decline rapidly in alkaline conditions.

half-life the time taken for the level of a treatment chemical to decrease to half its original value.

halogen a grouping of chemical elements that include bromine and chlorine.

heat exchanger a device for transferring heat between fluids which are not in direct contact with each other.

hypobromite ion (OBr–) a form of bromine predominant at higher pH levels. While it has biocidal properties, it is less effective as a biocide than HOBr.

hypochlorite ion (OCl–) a form of chlorine predominant at higher pH levels. While it has biocidal properties,it is less effective as a biocide than HOCl.

hypobromous acid (HOBr) the form of bromine that is most effective as a biocide.

hypochlorous acid (HOCl) the form of chlorine that is most effective as a biocide.

incubation temperature the temperature dip slides or inoculated culture media should be held at, for long enough for bacterial growth to become evident. The incubation temperature depend on the type of microorganism being tested for in the water sample.

scaling indices these are predictors for the scale-forming or corrosive properties of water.

legionnaires' disease a form of pneumonia caused by bacteria of the genus *legionella*.

legionella (plural legionellae) a bacterium (or bacteria) of the genus *legionella*.

Legionella pneumophila a species of bacterium that is the most common cause of legionnaires' disease and Pontiac fever.

make-up water fresh water added to a recirculating water system to compensate for losses by evaporation, bleed, drift, windage and leakage.

pH the logarithm of the reciprocal of the hydrogen ion concentration in water, expressed as a number between 0 and 14 to indicate how acidic or alkaline the water is. Values below 7 are increasingly acidic, 7 is neutral, and values higher than 7 are progressively alkaline. However, acidity and alkalinity are not proportional to pH (see **acidity** and **alkalinity**).

scale inhibitor chemical added to water to inhibit scale formation.

shot dose a single dose of a chemical, sometimes called a ‘shock’ or ‘shot’ dose. It can also describe routine high concentration periodic dosing (such as with non-oxidising biocides or dispersants) to distinguish it from maintaining a low concentration of chemical continuously.

total dissolved solids (TDS) the quantity of solids dissolved in the water, measured in mg/l. These solids will typically include calcium and magnesium (sodium in softened water), bicarbonate, chloride, sulphate and traces of other materials. TDS can be measured directly or determined indirectly from the conductivity reading (see **conductivity**).

total viable counts (TVCs) the total number of culturable bacteria (per volume or area) in a given sample.

turbidity the opacity of a liquid, eg cloudiness caused by a suspension of particles.

windage water lost when wind forces an unusual flow pattern through the base of a cooling tower and blows droplets out of the tower.

References

1 *Legionnaires' disease: The control of legionella bacteria in water systems. Approved Code of Practice* L8 (Fourth edition) HSE Books 2013 www.hse.gov.uk/pubns/books/l8.htm

2 *Health and Safety at Work etc Act 1974 (c 37)* The Stationery Office 1974 ISBN 978 0 10 543774 1

3 *Hazardous substances at work: A brief guide to COSHH* Leaflet INDG136(rev5) HSE Books 2012 www.hse.gov.uk/pubns/indg136.htm

4 *The Notification of Cooling Towers and Evaporative Condensers Regulations 1992* SI 1992/2225 The Stationery Office

5 *Reporting accidents and incidents at work: A brief guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations (RIDDOR)* Leaflet INDG453(rev1) HSE Books 2013 www.hse.gov.uk/pubns/indg453.htm

6 *Consulting workers on health and safety. Safety Representatives and Safety Committees Regulations 1977 (as amended) and Health and Safety (Consultation with Employees) Regulations 1996 (as amended). Approved Codes of Practice and guidance* L146 (Second edition) HSE Books 2012 ISBN 978 0 7176 6461 0 www.hse.gov.uk/pubns/books/l146.htm

7 BS 8580:2010 *Water quality. Risk assessments for Legionella control. Code of practice* British Standards Institution

8 *Guide to risk assessment for water services* The Water Management Society www.wmsoc.org.uk/publication.html

9 *A Recommended Code of Conduct for Service Providers* The Legionella Control Association 2013 www.legionellacontrol.org.uk.

10 *Water Fittings and Materials Directory* Water Regulations Advisory Scheme www.wras.co.uk/Directory

11 BS 6920-2-1:2000+A3:2008 *Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water. Methods of test* British Standards Institution

12 *Respiratory protective equipment at work: A practical guide* HSG53 (Fourth edition) HSE Books 2013 ISBN 978 0 7176 6454 2 www.hse.gov.uk/pubns/books/hsg53.htm

13 BS 7592:2008 *Sampling for Legionella bacteria in water systems. Code of practice* British Standards Institution

14 EN ISO/IEC 17025:2005 *General requirements for the competence of testing and calibration laboratories* British Standards Institution

15 BS 6068-4.12:1998, ISO 11731:1998 *Water quality. Microbiological methods. Detection and enumeration of Legionella* British Standards Institution

16 *The Health Protection (Notification) Regulations 2010* SI 659/2010 The Stationery Office

17 *The Public Health (Notification of Infectious Diseases) (Scotland) Regulations 1988* SI 1550/1988 The Stationery Office

18 *Guidance on the Control and Prevention of Legionnaires' Disease in England* Health Protection Agency 2010 www.hpa.org.uk

19 *Guidelines on Management of Legionella Incidents, Outbreaks and Clusters in the Community* Health Protection Scotland 2009 www.hpa.scot.nhs.uk

Further sources of advice

United Kingdom Accreditation Service (UKAS), 21–47 High Street, Feltham, Middlesex TW13 4UN www.UKAS.com

Public Health England (PHE)
www.gov.uk/government/organisations/public-health-england

Public Health Wales (PHW) www.publichealthwales.wales.nhs.uk

Health Protection Scotland (HPS) www.hps.scot.nhs.uk

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Further information

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