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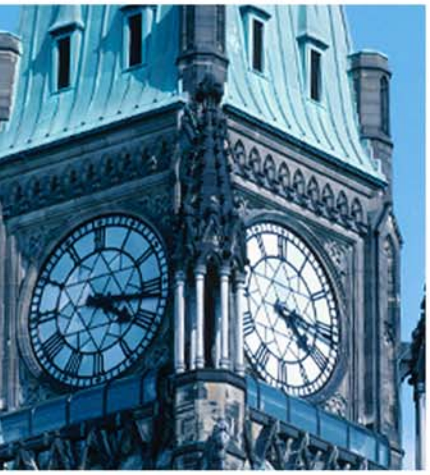

Control of Legionella in Mechanical Systems

Guidelines for Building Owners, Design Professionals, and Maintenance Personnel

Public Works and Government Services Canada
Travaux publics et Services gouvernementaux Canada

Canada

PWGSC

Mechanical Design Guidelines

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Mechanical and Maintenance Engineering

Professional and Technical Programs
Architectural and Engineering Resources Directorate
Real Property Branch
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Public Information

Introduction

General

This document has been developed by the Mechanical and Maintenance Engineering group of Professional and Technical Programs, Architectural and Engineering Resources Directorate, Real Property Branch, Public Works and Government Services Canada.

Feedback

Corrections, recommendations, suggestions for modifications or additional information and instructions that will improve this document are invited. For this purpose the attached form entitled “Request for change to this manual” may be used and mailed or faxed to the address shown. E-mail or other forms of electronic transmission may also be used for this purpose.

Conflicts

Any area of conflict between this document and the Project Brief/RFP shall be brought to the attention of the Project Manager as soon as it is noted.

MD15161 - 2006
Guidelines for the control of Legionella in mechanical systems
REQUEST FOR CHANGES

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Type of change suggested:

- ☐ Correction of information
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Details of suggested changes:

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Page: Chapter: Paragraph no:

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Chapter 1 General

1.1 Introduction

The name “Legionnaires' disease” was first used in 1976 after a respiratory disease affected many delegates attending a convention in Philadelphia held by the American Legion of Pennsylvania. There were 221 recorded cases of a strange illness that led, ultimately, to at least 34 fatalities. Eventually, the bacteria that was responsible for the disease was isolated and named as *Legionella* pneumophila. The source of the bacteria was traced to the hotel's water systems. Initially, the cooling towers were implicated, but further investigations revealed that deficiencies in the potable water system were the most probable cause of the disease.

Recently in 2005, there was an outbreak of Legionella's disease at a nursing home in Toronto, causing at least 20 fatalities while 127 people were diagnosed with a pneumonia-like lung infection that was possibly Legionellosis. The source of the bacteria was traced to a rooftop cooling tower, and the bacteria was spread to almost every floor by the building's ventilation system. The maximum age of the victims was around 90; the youngest victim was 40 years old. Some neighbours who lived across the street were also affected, possibly due to the mist from the cooling tower.

The Toronto outbreak highlighted the difficulties in identifying the disease. Although *Legionella* was suspected immediately after the outbreak, initial test samples failed to detect the disease, and conclusive evidence of Legionella was only found after analysis of the lung tissue from some of the deceased victims.

Two distinct illnesses, Legionnaires' disease and Pontiac fever, have been associated with Legionella bacteria. The milder form is Pontiac fever, an influenza-like illness that is rarely fatal. Legionnaires' disease is a much more serious form with severe pneumonia-like symptoms and it is often fatal.

The bacteria responsible for Legionnaires' disease belongs to the genus Legionella. There are approximately 35 Legionella species known to produce the disease and many of these species are commonly found in water bodies such as lakes and rivers. They can survive for several months in a wet environment and multiply in the presence of algae and organic matter.

Legionella is not an infectious disease as it cannot be transmitted from person to person. According to OSHA it is an “opportunistic” disease that most commonly attacks individuals who have a weakened immune system. Disease transmission normally occurs via inhalation of an aerosol of water contaminated by the bacteria.

Colonies of Legionella bacteria are found naturally in most water supplies. At temperatures below 20 deg.C they are dormant and get activated at higher temperatures.

Legionella could be a serious health concern in many public buildings. As the Toronto outbreak has indicated, diagnosis of the disease is by no means easy, and there is no reliable monitoring technique that can be used for early detection. Hence the only effective way of preventing such outbreaks in the future is the proper design, operation, and maintenance of components in mechanical systems such as cooling towers, air intakes and, water-distribution systems.

1.2 Purpose

The purpose of this document is to provide information, design criteria, and, guidance to minimize the occurrence of *Legionella* in public buildings.

1.3 Scope

The document applies primarily to commercial properties such as office buildings, laboratories, and, industrial buildings. It is intended to apply both to new and existing buildings.

The target audience for this document is property managers, engineers, designers, installers, maintenance contractors, and, property owners.

1.4 Legionella: An Overview

The major stages in the outbreaks of Legionnaires’ Disease are:

Proliferation and Amplification

This occurs in water supplies where the bacteria feed on available nutrients such as organic matter. The most favourable conditions for amplification of the bacteria include a temperature range of 25-42 deg.C, pH range of 6-8, stagnation of water supply, the presence of amoebae, and the formation of sludge, sediments, and bio-films. Natural products such as rubber and wood favor amplification, while growth is inhibited by metals such as copper. Almost all natural water supplies contain some Legionella causing bacteria, generally within safe limits.

Dissemination

Formation of aerosols such as mists, sprays, and droplets is the primary means of dissemination for *Legionella* bacteria. Cooling towers, evaporative coolers/condensers, water jet humidifiers, atomizers, spas, and, fountains are possible sources of dissemination of *Legionella* bacteria.

Transmission

Transmission occurs in a number of ways, and very often, the HVAC system is implicated. Most of the strategies for control of Legionella focus on reducing the means of transmission by proper location, design and operation of the mechanical systems. Transmission can occur through the building ventilation systems, air intakes, and, operable windows.

Inhalation

Deep inhalation of the Legionella is the primary source of infection. The attack rate is 2-7%, with an incubation period of 2-10 days. The risk of acquiring the disease is higher for elderly people, smokers, and, those with preexisting lung disease. Statistics indicate that women are three times more likely to get the disease than men.

The mechanical systems that may promote the growth of Legionella include:

- Cooling Towers
- Evaporative condensers
- Hot and cold water systems
- Taps and shower heads
- Spas and whirlpools
- Decorative fountains

In general, chemical treatment using biocides alone is insufficient for Legionella control. A “best practices” approach that combines chemical treatment, cleaning, maintenance, sterilization, and monitoring is recommended.

1.5 History of this Document

In view of the concerns expressed over the implication of mechanical systems in the spread of Legionellosis and Legionaires' Disease, an exhaustive study of the subject was conducted in 1985-1986 by the Mechanical Engineering Division, Headquarters branch, Public Works Canada, in conjunction with the Health Protection Branch, Health and Welfare Canada. As a result of this study, the original Mechanical Design Standard on Legionella control was published in 1986. There have been no revisions to the document since 1986.

The document has now been rewritten considering the latest research in this field, and the publication of several new guidelines and standards, including ASHRAE Guideline 12-2000:*Minimizing the Risk of Legionelossis Associated with Building Water Systems.*2004.

Chapter 2 The use of Biocides for Legionella Control

2.1 Introduction

Biocides are compounds selected for their ability to kill microbes, but with low toxicity to humans, plants, and, animals. For Legionella control, they are generally employed in the water treatment system of cooling towers and in the water supply system. Very often, biocides are the primary line of defense against Legionella.

The ideal biocide should be effective against a wide range of bacteria, algae, protozoa and fungi, and should have a long activity time. It should have no toxicity to humans, and be environmentally acceptable. It should be quick acting and effective at low concentrations over a wide pH range. It must be compatible with other chemicals used, and should not cause deterioration of materials with which it comes into contact. It should be capable of penetrating foam, sludge, slime and scale within the system without foaming.

The effectiveness should not be reduced by contaminants within the cooling tower system or by substances present in the make-up water. Its concentration should be easily measurable using simple test procedures.

There are no biocides that meet all of these requirements. In practice, it is often necessary to use more than one type of biocide to achieve desired results.

There are two types of Biocide: Oxidizing and Non-oxidizing.

2.2 Oxidizing Biocides

Oxidizing biocides include chlorine, bromine, and, chlorine dioxide. Chlorine and bromine react very rapidly with microbiological species and chemicals in the water. This reactivity is both their strength and weakness. Rapid reaction means a quick and effective kill but it also means that the biocide reacts very quickly with other chemicals in the system, such as scale inhibitors and corrosion inhibitors. Hence, they leave very little residuals for continuous protection against bacteria.

Chlorine-and bromine-based formulations are only effective at concentrations exceeding 0.5-1 ppm; these levels can, however, cause rapid corrosion of piping materials. Also, the effectiveness of these biocides varies with pH, and careful control of pH in the range of 7-10 is required. Chlorine-based formulations do not penetrate biofilms very easily; hence, some form of dispersant may also be required.

Chlorine is generally used in the form of Sodium Hypochlorite, a chemical that liberates free Chlorine in the presence of water.

Chlorine Dioxide has better properties than Chlorine or Bromine for Legionella control. It is fast acting, environmentally friendly, less corrosive, and very effective at concentrations as low as 0.1 ppm. It does not lose effectiveness over a wide pH range of 4-10. Also, it penetrates biofilms where Legionella bacteria accumulate.

Chlorine dioxide is approved in many countries for potable water treatment. It can be fed to domestic cold water systems well as to heating water system. Feeding chlorine dioxide to the domestic cold water system delivers better water protection as it treats the system further upstream and allows more contact time for killing the bacteria. Even at maximum feed rates, Chlorine Dioxide leaves no noticeable taste or odour impact on the water. It is approved and recommended by the US EPA as an environmentally-friendly water additive.

Chlorine Dioxide should be produced on site, as its transportation is dangerous. In fact, its transportation is forbidden under the US Federal laws. There are several methods of producing Chlorine Dioxide in site, generally using Sodium Chlorite as the starting point. Addition of an acid to this chemical produces Chlorine Dioxide that can be fed directly to the water being treated. Electrolytic methods eliminate the need for using an acid, resulting in a very “clean”, environmentally-friendly technology, using portable generation equipment.

Ozone is also highly effective against Legionella at concentrations of 0.1-0.5 ppm but its use is limited due to its toxic nature.

Bromine is moderately effective against Legionella, and it requires a higher concentration of 0.5-1.5 ppm. It is more effective than Chlorine as a biocide at higher pH. Stabilized Bromine Chloride at concentrations of 4-10 ppm may also be used as a biocide.

Other oxidizing biocides include Sodium Bromide, Bromo-chlorohydontain, Iodine, and Icocyanurates. Bromine and Iodine-based biocides are generally less corrosive than Chlorine-based formulations.

2.3. Non-Oxidizing Biocides

Non-oxidizing type biocides include organic compounds such as BNPD (2 Bromo-2-Nitro Propane-1, 3, diol), glutaraldehyde, Dithiocarbamates, isothiazoline, DBNPA (Di-bromo-nitrilo-propionamide) and, some quaternary

ammonium compounds. These chemicals are typically slow to act and are added to the cooling tower in large, weekly doses, then allowed to decrease until the next addition. This type of treatment is based on overdosing the system during addition, and then leaving a residual that destroys the bacteria over a period of time. See Table 1 below for recommended doses of these biocides.

Table 1 Legionella control with non-oxidizing biocides

Chemical Compound	Active Concentration mg/l	Contact Time
Glutaraldehyde	25 - 54	1 Hour
Isothiazolin	2.25 - 2.6	6 Hours
2 Bromo-2-Nitro Propane-1,3, diol	25	24 Hours
(BNPD)	400	60 Minutes
Dithiocarbamates	40.0 - 60.0	6 Hours
Di-bromo-nitrilo-propionamide (DBNPA)	4 - 8	2 Hours
Note: System potential contaminants and operational pH must be checked for compatibility with the non-oxidizing biocide **Courtesy: Drew Industrial/Ashland Canada Corp**.		

Non -oxidizing biocides have several drawbacks. They are often toxic to humans and to animal species. They are dangerous to store and handle, and disposal of cooling water containing these chemicals can be difficult and costly, due to environmental regulations. These biocides must be used in large quantities and are often more expensive than oxidizing biocides.

2.4 Non-chemical Methods

Ultraviolet Germicidal Irradiation (UVGI) is sometimes used as a biocide. However, careful design of the system is essential, to ensure that the bacteria get adequate exposure for an adequate period of time for full effectiveness of the procedure. Proper maintenance of the equipment is also required.

Water ionization is a new technology for destroying bacteria that does not require the use of chemicals. In this system, water flows between electrically-charged electrodes that dissipate very low concentrations of copper and silver ions into the water. The ions destroy the microorganisms and safely disinfects all of the water system without any corrosion problems.

2.5 Alternating the Use of Biocides

Alternating the use of different types of biocides during water treatment minimizes the growth of resistant strains of bacteria. Alternating the dose and frequency of application is also helpful.

A good biocide program includes the use of alternate types of biocides at regular intervals and at the proper legal dosage. This strategy minimizes the development of resistant strains of bacteria. A typical program uses an oxidizing biocide such as Chlorine alternated with a non oxidizing biocide such as isothiazolone or glutaraldehyde.

Chapter 3 Legionella Control in HVAC Systems

3.1 Design of Cooling Towers Systems

3.1.1 General

Cooling towers and evaporative condensers are potential sources of Legionella disease, because they can develop dangerous concentrations of the bacteria. Stagnant water in the cooling towers provides favorable conditions for the growth and amplification of the Legionella bacteria. In addition, cooling tower drift (water loss) causes mists or plumes that can transmit the disease-causing bacteria.

The evaporative cooling process concentrates all impurities, including microorganisms, and allows the impurities to stay for a longer time in the water loop. Hence it can produce conditions favourable for bacterial growth.

Many of these problems can be eliminated with good engineering practice; hence, proper design and operation of cooling tower systems should be the primary defense against Legionella.

3.1.2 Design Requirements

1. Cooling Towers should be equipped with high performance drift eliminators.

2. The design air velocity through the fill and the drift eliminators should not exceed 3 m/s (588 ft/min).

3. There should be no bypass of air around the drift eliminators.

4. The drift eliminators should be easily removable for cleaning or replacement.

5. There should be no leakages in the tower casing.

6. Tower construction material in contact with the water should be corrosion resistant and compatible with disinfectants, biocides, and, cleaning agents.

7. To facilitate inspection and cleaning of internal surfaces, bolted and/or gasketted access openings should be provided.

8. Cooling tower basins should be designed for cleanability.

9. Wetted surfaces should be protected from direct sunlight to minimize bacterial growth under warm conditions.

10. Water must not be allowed to stagnate, by eliminating dead legs and reservoirs for water storage.

11. Eliminate short circuiting of cooling tower air with the discharge back into the cooling tower inlet.

12. An enclosure should be provided for the area above the cooling tower sump, to reduce the effects of windage that cause the drift to escape from the sides. It should not be made of any transparent material, as sunlight promotes the growth of algae.

3.1.3 Cooling Tower Location

1. Cooling towers should be located far from the building's operable windows, air intakes, to eliminate possible contamination of the air-distribution system.

2. The cooling towers should be located far from the air intakes in adjoining buildings.

3. The minimum separation distance should be 5 metres between the cooling tower and any air intake. However, a larger separation distance should be used if there is any possibility of contamination. In such cases, computational fluid dynamic studies, or wind tunnel modeling should be undertaken.

4. To determine the optimum location of the cooling tower, also consider site factors such as height of adjacent structures, direction and velocity of prevailing winds, and, the presence of enclosures and screenings around the cooling towers.

3.1.4 Water Quality Control

Include provisions for:

1. Automatic continuous bleed,

2. Manual cleaning at regular intervals,

3. Application of scale and rust inhibitors, on a continuous basis,

4. Application of biocides through slug (shock) dosing at timed intervals using automatic equipment . Manual dosing should not be used.

3.1.5 Annual Startup Procedure for Cooling Towers

No building should be handed over, accepted or put into service until commissioning of the cooling tower is successfully completed. Commissioning should include, but not necessarily be limited to, the following:

1. Thorough clean-out of all cooling-tower mechanical equipment

2. Shock chlorination of the whole system including the cooling-tower distribution basin and fill with the circulating pump(s) in operation. During shock chlorination, the pH should be less than 7. Free chlorine residual of at least 5 ppm should be maintained for at least 6 hours, or, alternatively, a residual of 15 ppm for at least 2 hours. The cooling tower fan should be turned OFF during the shock chlorination.

3. This should be followed by continuous, automatically-controlled feed of a suitable biocide with scale and rust inhibitors.

3.1.6 Drains and Overflows

Discharge from cooling tower drain and/or overflow should be connected into the sanitary sewer such that back pressure, surcharge and/or reverse flow cannot occur in the sanitary drain or sewer and, aerosolization of the discharge cannot occur.

3.1.7 Evaporative Cooling Towers

In evaporative cooling systems, ventilation air passes through a wetted medium, and the evaporation of the water cools the ventilation air as it passes through.

In most evaporative cooling systems, water normally collects in a basin or sump for recirculation creating a potential site for microbial growth. When the system is in use, the low water temperature minimizes the possibility of bacterial growth. However, if the system is idle, water temperature may rise and provide an amplification site for Legionella. Hence, evaporative coolers must be kept dry when not in use.

3.2 HVAC: Other Systems and Components

3.2.1 Air filtration Equipment

1. Where there is a possibility of contamination of air intakes by cooling towers, evaporative condensers or fluid coolers, high efficiency filters with a MERV rating of at least 12 should be installed at the air intake.

2. The air filter assembly should be designed to prevent contamination of the air supply during scheduled maintenance.

3.2.2 Humidifiers for Central HVAC Systems

1. Acceptable types:

Humidifiers forming part of any HVAC system should be steam injection type, providing that the chemical treatment of the steam is not injurious to human health.

2. Prohibited types:

Evaporative pan or drum type, atomizing water spray type and sprayed coil type humidifiers should not be used. During renovation projects, existing humidifiers of the evaporative pan or drum type, atomizing water spray type or sprayed coil type should be replaced with approved type of humidifiers.

However, existing water spray humidifiers in existing buildings are permissible if proper precautions are taken to minimize Legionella. The precautions include regular scheduled maintenance, and total avoidance of water stagnation in the humidifiers.

3.2.3 Cooling Coil Condensate Drain Pans and A/C Unit Drains

Cooling coil condensate drain pans should be designed for easy cleaning. They should be designed to eliminate standing water in the pan. Drain connections should be in the bottom or in a depression in the side of the pan.

Cooling coil condensate drain pans and air conditioning unit drains should be equipped with deep seal trap rated for twice the maximum static pressure in the system.

3.2.4 Room Humidifiers

The use of room humidifiers should be avoided, as they can provide a ready source of aerosols for dissemination of Legionella. If, however, their use is essential they must use only sterilized water.

3.2.5 Water Fountains

The use of water fountains is not recommended for new buildings, as they are potential amplification sites for Legionella. However, water fountains are found in some existing buildings, and their use is permitted, if proper operation and maintenance procedures are followed, as indicated below:

1. Water should not be allowed to stagnate; it should be in continuous circulation.

2. Sludge formation should be eliminated through regular cleaning procedures at regular intervals, at least once every 3 months.

3. The plumbing system for the water fountains should be free of dead-legs

3.3 Operation and Maintenance of HVAC Systems

3.3.1 Maintenance Data

An approved data base should be maintained for all HVAC equipment, using existing PWGSC Maintenance Management Software. The database should include details of observations during inspections, results of tests, history of all maintenance activities.

The pH of chlorinated water systems should be monitored at frequent intervals and the results recorded. For maximum effectiveness of Chlorine-based biocides, the pH should always be maintained between 7.0 and 10.0.

Operation and maintenance records should include a system schematic, system water volume,manufacturers instructions for equipment maintenance, Material Safety Data Sheets (MSDS) , inspection records, date and description of all maintenance activities, date and description of all equipment repair and modifications, and, names of persons responsible for operation, maintenance and shutdown.

3.3.2 Monitoring for Legionella

A monitoring program for Legionella Disease should not be considered a substitute for sound engineering practice. Very often, the monitoring program will fail to detect the onset of the disease in time for corrective action as results of monitoring tests are difficult to interpret. In addition, there is no standardized procedure for performing these tests. Also, the test results only represent the bacteria counts at the time of collection of the sample, and may lead to a false sense of security. It generally takes 2 to 10 days to develop Legionella cultures, and, again, the results of the tests are not always conclusive.

During the recent outbreak of Legionella at a nursing home in Toronto, water samples from the cooling towers failed to detect the disease. A conclusive diagnosis could only be made after testing of tissue cultures after autopsy of some of the victims. In this case, a monitoring program would not have successfully detected the Legionella disease in the building's water systems.

There is no simple correlation between the presence of the organism and the risk of infection. The bacterium is often present in water systems without being associated with any known case of the disease. Also, the risk of illness depends on many factors other than exposure, including host susceptibility, strain virulence, and efficiency of aerosolization.

Monitoring may, however, be useful when carried out for a specific purpose such as verifying the effectiveness of a water treatment method or tracing the source of an outbreak.

3.3.3 Cleaning Schedule for Cooling Towers

Cooling towers should be maintained in a clean working condition whenever they are in use. Each system should have a maintenance manual that includes building plans of cooling and ventilation systems, cleaning methods, decontamination procedures, dismantling instructions, procedures for water treatment, shutdown and startup procedures. Cleaning schedules should be incorporated into the RPMS software that is used by PWGSC for building maintenance. The building SOP should also include the procedures for the control of Legionella, as described in the present document.

Proper cleaning and water treatment on a regular basis is essential for minimizing the risk of Legionella in cooling towers. Cooling towers should be categorized as follows:

Category 1:

Where cooling tower is in use for six (6) months or less.

Category 2:

Where cooling tower is in use for more than six (6) months.

The following cleaning schedule is recommended:

Table 1 Cleaning schedule for cooling towers

Category	Inspection	Cleaning	Water treatment
1	weekly	once, during cooling season	At beginning of cooling season
2	biweekly	twice, during cooling season	At beginning of cooling season

However, cooling towers which persistently collect visible bacterial growth should be inspected and cleaned more often. Inspections should include tests for free chlorine residuals, and, simple indicator tests (such as dip slides) for bacterial growth.

After a cooling tower has been taken out of service for more than three (3) days, it should be sterilized by shock chlorination with circulating pump(s) in operation. If it has been out of service for more than 30 days, the full startup procedure indicated in Section 3.1.5 should be followed.

Evaporative condensers and fluid coolers should follow a similar cleaning schedule.

3.3.4 Monthly Inspections for Cooling Towers

Cooling towers should be inspected at least once a month as part of a regular preventive maintenance program. The inspection should include:

1. Examination under normal working conditions Examine for signs of microbial growths, algae, water leaks, splashing, blockages or restrictions at air inlets. Examine chemical dosing equipment for correct operation and for adequate stock of chemicals. Examine water

flow through the tower for normal unrestricted flow. Examine drift eliminators internally and externally for damage and for excessive drift.

2. With the fan, water pump dosing and filtering equipment switched off, examine the internal structure of the tower for condition of plant and equipment. Report any deterioration of materials, particularly the fill, drift eliminators, basin and water distribution system.

3. Internal surfaces should be examined for signs of corrosion, scale, microbial growths and general fouling and the water checked for clarity.

3.3.5 Annual Inspections for Cooling Towers

More detailed inspections should be undertaken annually. This should include:

1. Inspection of the interior of pumps, sections of pipework, heat exchange equipment.

2. Assessment by a water treatment specialist of the relevance of any signs of corrosion biofilms or deposits.

3.3.6 Chemical Water Treatment for Cooling Towers

Chemical Water treatment generally involves the following steps:

1. Application of corrosion inhibitors.

2. Application of surfactants and other chemicals to control fouling due to formation of bio-films

3. Application of biocides to control the growth of bacteria.

Interactions between the chemicals must be considered when planning the water treatment program. For example, Chlorine based biocides tend to react very rapidly with surfactants, reducing their effectiveness.

Dosing points should be in the turbulent zones of the distribution system to ensure rapid dilution and mixing. Methods of dosing application include:

1. continuous drip feed.

2. Slug or shock dosing.

3. Metered dosing.

3.3.7 Maintenance for Cooling Towers

Maintenance involves regular checking of components, cleaning of wetted surfaces, and, provision of water treatment. The aim is to ensure optimum thermal performance. These maintenance procedures should be put into practice as soon as the cooling towers are put into service.

3.3.8 Routine Cleaning and Disinfection for Cooling Towers

1. Frequency: As a general guide, cleaning should be carried out every three months.

2. When a cooling tower has been shut down for a prolonged period, the routine cleaning and disinfection procedure should be carried out prior to starting up the equipment.

3. Relevant performance data determining the frequency of cleaning should be based on total bacteria count (TBC).

A recommended procedure for routine cleaning and disinfection is as follows:

1. Implement Occupational Health and Safety Procedures as prescribed in the OSHA manual.

2. Add a low foaming detergent, compatible with sodium hypochlorite, to the circulating water.

3. Add 250 mL of 12.5% commercial sodium hypochlorite solution per 1,000 litres of water contained in the system, slowly, over five to ten minutes, to a turbulent zone of the basin to promote rapid dispersion. Use an anti-foaming agent if excessive foaming occurs.

4. Circulate the water for at least one (1) hour throughout the system to provide coarse cleaning of the wetted surfaces.

5. Switch off equipment and drain to waste in a manner approved by the local water authority. The use of a wet vacuum cleaner may facilitate the removal of waste material from the basin floor.

6. Thoroughly clean the internal shell, fill and sump off the cooling tower, moving or flushing away all debris.

7. Refill with clean water.

8. Chlorinate the water to maintain at least 5mg/L free chlorine residual, keeping the pH between 7.0 and 10.0. Circulate the water for one hour under these conditions. Free chlorine residual should be measured using a DPD test kit.

9. Discharge the water to waste.

10. Inspect the drift eliminators and, if necessary, remove for cleaning, repair or replacement.

11. Refill with clean water and treat as required.

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Chapter 4 Legionella Control in Domestic Water and Heating Water Systems

4.1 Design of Domestic Water Systems

4.1.1 General

Water systems have been implicated in several cases of Legionella outbreak. In fact, there is some evidence that the first recorded Legionella outbreak in Philadelphia in 1976 was in fact caused by the hotel's water distribution, and not by the cooling towers as reported initially. Hence proper design and operation of the water system is essential for Legionella control.

Legionella bacteria proliferate most rapidly in the 25-42 deg.C temperature range. Below 20 deg.C, the bacteria are dormant and relatively harmless. The bacteria do not survive at temperatures above 49 deg.C. Maximum bacterial growth occurs at a temperature of 42 deg.C.

Hence cold water temperatures should be maintained at below 20 deg.C (68 deg.F) while the lowest temperature in the hot water system should be over 49 deg.C(121 deg.F).

A hot water storage temperature of 60 deg.C is preferred, for most effective protection against the growth of Legionella. However, this is not practicable in all cases; hence, the following is recommended:

1. For existing facilities, the minimum hot water storage temperature should be 49 deg. C unless there is a high risk of Legionellosis in a specific building, in which case the minimum storage temperature should be 60 deg.C.

2. In addition, the requirements of local building codes should be met, if applicable.

3. For new buildings, a minimum hot water storage temperature of 60 deg.C is recommended, with the use of mixing valves to bring the temperature down to 35-43 deg.C at the distribution points. It should be noted that the Canada Occupational Health and Safety Regulations also require a temperature of 35-43 deg.C at the

distribution point.

4. For retrofits, the minimum hot water storage temperature should be 49 deg. C unless there is a high risk of Legionellosis in a specific building, in which case the minimum storage temperature should be 60 deg.C.

5. For laboratories and hospitals, the minimum hot water distribution temperature should be 60 deg.C.

4.1.2 Design of Domestic Hot Water Storage Tanks and Heaters

1. Do not oversize the water storage tanks as this may result in improper water circulation.

2. Storage tanks should have no pockets from which scale, sediment and sludge would be difficult to remove.

3. Access manholes should be provided for visibility of deposits and for easy maintenance of the tanks.

4. The use of instantaneous water heaters should be considered, either as stand-alone devices, or used in conjunction with storage heaters.

5. The storage tanks should be designed to permit sterilization at a temperature of at least 75 deg.C.

4.1.3 Design of Distribution Piping Systems

1. Copper should be used for all domestic water piping systems.

2. The use of natural rubber, silicone or PVC Pipe should be avoided, as these materials can provide nutrients for growth of bacteria.

3. Cold water piping should be located below hot pipes to minimize the potential for warming up due to convection.

4. The piping system should be designed to eliminate dead legs.

5. Piping between the faucet and the circulating mains should be as follows

Table 2 Maximum piping length

Type of Pipe	Maximum length between faucet and circulating main, metres
NPS 1/2	10
NPS 3/4	5
NPS 1	2

6. The piping systems should be designed to prevent the formation of pockets of stagnant water at any point. As an example, the use of drain valves with “dirt pockets” for collection of sediment should be avoided.

7. The plumbing for circulating mains should be designed to be drained through plumbing fixtures and not through drain valves in the mains.

8. Consider the provision of booster chlorination to the domestic cold water system, using an automatic system. At least 3 ppm of free available chlorine in the system should be maintained, if Chlorine is used as a biocide. Provision should be made for adjustment of the pH to between 6.5 to 8.5 when using Chlorine. Chlorine Dioxide may also be used as a biocide. Non-chemical means of destroying bacteria, such as electrolytic methods, should also be employed wherever appropriate.

9. Chlorine feed by constant capacity units should not be used

10. If flexible shower hoses are employed, the lining material should be resistant to biocides and be incapable of providing nutrients for microbial growth.

11. Natural rubber and leather should not be used in plumbing systems, since they are known to be a source of nutrients for Legionella bacteria. Washers and gaskets should be of neoprene or other synthetic material that does not support microbial growth and is resistant to biocides.

4.1.4 Sterilization of Domestic Hot Water Systems

1. Before any domestic hot water Storage tank or heater is commissioned, it should be sterilized at a temperature of at least 75 deg.C maintained for at least 48 hours.

2. Before any domestic hot water system is commissioned it should be thoroughly flushed out and disinfected using a chlorine-producing agent with a residual of at least 2 ppm for 24 hours, or another suitable biocide, followed by thorough flushing.

4.2 Operation and Maintenance of Domestic Water Systems

4.2.1 General Requirements

The requirements stated in this section are over and above the regular maintenance requirements for the system.

4.2.2 Maintenance of pH in Chlorinated Plumbing Systems

The pH value of all chlorinated plumbing systems should be monitored at frequent intervals and the results recorded. For proper results, pH should be maintained in the 7-10 range , when using Chlorine-based biocides.

4.2.3 Thermostatic Mixing Valves

1. Flush out weekly at full flow for 15 seconds.

4.2.4 Shower Heads

1. Heat disinfect monthly using hot water at 70°C for at least 5 minutes.
2. Outlets that are infrequently used should be flushed at full flow for at least 15 seconds on a weekly basis.

4.2.5 Dead Legs and Stagnant Water Pipes

Dead legs and pipes containing stagnant water which lie idle for more than one week should be flushed at full flow for at least 15 seconds.

Chapter 5 Decontamination procedures

5.1 Decontamination of Infected Cooling Towers

5.1.1 General Requirements

1. Implement decontamination procedures whenever:

   1. Legionella bacteria counts exceed 1 000 cfu (or other value as established by the authority having jurisdiction).

   2. Any other tower in same locality has Legionella counts exceeding this value.

   3. An outbreak of Legionella Disease has occurred in the locality.

   4. The cooling tower is in a very dirty condition as determined by a visual inspection.

2. Decontamination procedures should include chemical disinfection, scrubbing, de-sludging and cleaning using chlorine (released from sodium hypochlorite).

3. Special circumstances such as the conditions of the materials of the cooling tower or the alkalinity of the water may make the use of chlorine impractical. In that case, other approved biocides may be used.

5.1.2 Decontamination Procedures

Decontamination should be in accordance with the following procedures:

1. Implement Occupational Health and Safety procedures as prescribed in the OSHA manual.

2. Stop any chemical treatment; isolate all electrical equipment except the water-circulating pump.

3. Add a low foaming detergent, compatible with sodium hypochlorite, to the circulating water.

4. Add 500 mL of 12.5% sodium hypochlorite disinfectant per 1,000 litres of cooling water contained in the system slowly, over 5-10

minutes, to a turbulent zone of the tower basin to promote its rapid dispersion. Use an anti-foaming agent if excessive foaming occurs.

5. Circulate the water for a minimum of one hour throughout the system to provide coarse cleaning of the wetted surfaces and give a measure of disinfection even though the initial free chlorine level is not maintained and the pH is not controlled during this operation.

6. Switch off the circulating pump and drain the system to waste. The use of a wet vacuum cleaner may facilitate the removal of waste material from the basin floor.

7. Refill with clean water and start the water-circulating pump.

8. Add 100 mL of 12.5% sodium hypochlorite disinfectant per 1,000 litres of cooling water.

9. Keep the pH between 7.0 and 7.6 and maintain a concentration of 10 mg/L (l0 ppm) of free chlorine residual, as measured using a DPD test kit, by further addition of sodium hypochlorite as necessary.

10. Circulate the water for three hours under these conditions, and then switch off the circulating pump and drain to waste.

11. De-sludge and thoroughly clean the tower sump, internal shell and all internal fittings by brushing and hosing all surfaces. Suitable precautions should be taken to minimize the release of aerosols during cleaning operations, especially where air intakes are sited in close proximity.

12. Remove drift eliminators and thoroughly clean, repair or replace as necessary.

13. Thoroughly clean all water filters, strainers, water nozzles and fittings associated with the water distribution system.

14. Re-assemble all components and hose the system with clean water.

15. Refill with clean water and switch on the circulating pump.

16. Chlorinate the water to maintain at least 5 mg/L (5 ppm) of free chlorine residual, keeping the pH between 7.0 and 7.6. Circulate the water for a minimum period of three hours under these conditions.

17. Switch off the circulating pump and drain to waste.

18. Refill with clean water and switch on the circulating pump.

19. Repeat items 16. and 17. if the water is not visually clear. Clean the water filters, strainers, and

repeat item 18. Repeat this sequence until water quality is satisfactory.

20. Re-commission the plant when the water is free of turbidity and immediately institute chemical water treatment.

21. Record details in the maintenance log book.

5.1.3 Water Treatment after Decontamination

Chemical treatment of the cooling tower water should be reviewed at this stage and the entire cooling tower installation examined for faults in location, design, operation and maintenance procedures.

These faults should be corrected and a more reliable regimen of water treatment instituted as necessary.

5.1.4 Bacteriological Examination after Decontamination

1. The water of a decontaminated cooling tower should be tested bacteriologically to assess the efficacy of the procedure.

2. Water samples should be taken 24-48 hours after recommissioning for the determination of total bacterial count (TBC) and the presence of Legionella bacteria.

3. TBC should be low at this stage (less than 1,000 cfu per mL) and tests for Legionella bacteria should be negative. If this is the case, a further check on these parameters should be taken after one month and again a month later. If Legionella bacteria is not detected, and the TBC is less than 1,000 cfu/ml no further testing is required at this time.

4. If the testing of water samples still shows the presence of Legionella bacteria, the cooling tower should again be subject to the decontamination procedure plus a critical review of all associated equipment and the water treatment protocol.

5.1.5 Decontamination of Domestic Water Distribution Systems

1. When a system is suspected as the source of Legionnaires' Disease, a mechanical inspection should be undertaken immediately without waiting for test results from water samples.

2. Suspected fittings, including faucets, shower heads and, associated washers o-rings should be investigated for the presence of Legionella. Swabbing of the piping connected to the fittings should be performed and the swabs should be cultured for Legionella.

3. Decontamination procedures should be developed as the design proceeds, should be specific to the

project, and should include records of hot and cold water temperatures at various points in the system and the investigation of water samples taken at various points and in an approved manner. Project-specific decontamination strategies should be developed in conjunction with Health Canada and other Government agencies.

4. Decontaminants should include, as appropriate to the system and/or equipment: Chlorine, Chlorine Dioxide, Ozone, Bromine,and, special formulations.

Chapter 6 Glossary

Aerosol

A suspension in a gaseous medium of solid particles, liquid particles or solid and liquid particles having negligible falling velocity

Airborne water particles are usually less than 5 micron in diameter and are breathable into the lower areas of the lungs

Algae

Small, usually aquatic, plants which require light to grow. They are often found growing on the exposed surfaces and edges of cooling towers, and in open air water tanks

Amplification

The growth of Legionella bacteria from a low concentration to a high concentration, usually at amplification sites

Bacterium (plural bacteria)

A microscopic unicellular organism, capable of independent growth

Biocide

A substance which kills microorganisms.

Biofilm

The concentration of nutrients and microorganisms in the interface between liquid and solid surfaces. Can readily accept Legionella bacteria

Bleed

Water discharged from a cooling tower water system to control the concentration of salts and other impurities in the circulating water. Usually expressed as a percentage of the recirculating water flow

Biofouling

Excessive microbiological growth (such as from algae, slime forming bacteria and sulfite reducing bacteria) which can lead to blockage and uneven water distribution in a water system. Reduces the effectiveness of heat exchangers

Chlorinate

To add chlorine to the water, often in the form of sodium hypochlorite

Cooling tower

An apparatus or system through which warm water is discharged against an air stream, in doing so evaporation occurs and cools the water

Corrosion inhibitor

A chemical designed to prevent or slow down the corrosion of metals, generally in piping

Deadleg

A length of pipe containing water, temporarily or permanently blocked at one end.

Detergent

A cleansing agent capable of penetrating biological films, sludge and sediment and having the ability to emulsify oil and hold materials in suspension

Dezincification

The process of corrosion of copper/zinc alloys involving loss of zinc

Dipslide

A glass or plastic slide coated with culture media on which microorganisms can be grown and estimated

Disinfection

Reduction of population of microorganisms using chemical or physical means. Not necessarily the same as sterilization

Dispersant

A chemical usually added with other treatment chemicals to loosen organic material adhering to surfaces and prevent accumulation of sludges

Dissemination

A mechanism which permits transfer of Legionella from the reservoir to the point of exposure to people

DPD test kit

A kit for measuring free, combined and total chlorine residuals using the reagent DPD (N,N-diethyl-p-phenylene diamine)

Drift

The water aerosol which emerges from the airflow outlet of a cooling tower. It is distinct from “plume”

Drift eliminator

Equipment containing a complex system of baffles designed to remove water aerosols

Evaporative cooler

A device that provides cooling by evaporation of water in an airstream

Evaporative condenser

Equipment which circulates water to wet a condenser coil and directs air over the coil to provide evaporative cooling

Fouling

Organic growth or other deposits on heat transfer surfaces causing loss of heat transfer efficiency

Free Chlorine

Free Chlorine refers to the active form of Chlorine that is available as a disinfectant, as opposed to the “combined” form of Chlorine that is not available for disinfectation. For example, salt water has no free chlorine; it is all combined as Sodium Chloride

Free Chlorine generally refers to the hypochlorous and the hypochlorite ions in aqueous solutions, and is measured in parts per million (ppm)

Habitat

The natural environment for the growth of bacteria

Legionella

A genus of bacterium causing Legionnaires' Disease

Legionnaires' disease

An illness characterized by pneumonia, caused by infection with Legionella species such as Legionella pneumophila

Legionellosis

Another name for Legionnaires' disease

mg /L (ppm)

MERV

Acronym for “Minimum Efficiency Reporting Value”. The MERV rating is the standard method for comparing the efficiency of an air filter. The higher the MERV rating, the better the filter is at removing particles from the air

Milligrams per litre (parts per million)

Nebulizer

A device used to generate aerosols for room humidification. Usually found in health care facilities

Outbreak

Two or more cases of a disease linked by a common cause

pH

A scale used to describe the hydrogen ion concentration in an aqueous. Pure water has a pH of 7.5. A smaller value indicates an acidic condition; a number greater than 7.5 is alkaline.The range of values is 0-15

Plume

A cloud of water vapour emerging from a cooling tower. It is not the same as “drift”

Pontiac fever

A self-limited short-duration, non-fatal fever caused by Legionella bacteria. The incubation period of the disease is from 5 h to 66 h, and the attack rate is up to

95 percent. Symptoms include chills, headache, muscle pain, and other flu-like symptoms

Potable water

Water that is suitable for drinking purposes

Ppm

Parts per million

Reservoir

A site where bacteria has been found

Scale inhibitor

Chemical added to water to inhibit formation of scale.

Slime

A mucous-like material which is produced as part of an organisms metabolism- and allows adherence of protective layer to surfaces

Sludge

A general term for soft mud-like deposits on heat-transfer surfaces or other important sections of a cooling system

Sodium hypochlorite

A chlorine-releasing water soluble chemical used for disinfection

Surfactant

A soluble surface acting agent that reduces surface tension of water

Sterilization

The process of eliminating all disease-causing organisms in a piece of equipment. Sterilization is not necessarily the same as disinfection

Total bacteria count (TBC)

An estimate of the number of viable units of bacteria per millilitre of water under the conditions of testing

Total dissolved solids (TDS)

The total weight of dissolved substances in water

Turbidity

A cloudy appearance in water that is caused by a suspension of colloidal or particulate matter

Windage

Physical loss of water from the base of a cooling tower caused by wind of unusual pattern passing through it

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7.2 Web- Based Resources

http://www.accepta.com

http://www.breezair.ie/legionnaire.htm

http://www.ccohs.ca/oshanswers/diseases/legion.html

http://www.coolingtowerionization.com/Legionella048.html

http://www.epa.gov/ost/humanhealth/microbial/Legionellafs.pdf

http://www.hcinfo.com

http://www.osha.gov

http://www.cdc.gov

http://www.ashrae.org

http://www.cti.org

http://pathcon.com

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http://www.Legionella.com

http://www.nea.gov.sg/cms/qed/cop_Legionella.pdf

Appendix A Stages in Outbreaks of Legionellosis

A.1 General

This document refers primarily to the engineering aspects of Legionella control, and details about the signs and symptoms of the disease, diagnosis, treatment, prognosis, and risk factors are not included.

A.2 Occurrence

1. Legionella bacteria is found naturally in most lakes, rivers and streams, generally at low concentrations. They survive the processes used in most water treatment plants, but at these concentration they are generally harmless. Attempts to detect the bacteria at the outlet of treatment plants and in large municipal water distribution mains have proved unsuccessful possibly due to lack of suitable techniques.

A.3 Survival

Survival of Legionella bacteria depends upon:

1. Temperature: The temperature range for growth is 77-108°F (25-42°C). Optimal growth occurs at 95-99°F (35-37°C). Below about 68°F (20°C), they are generally dormant. They are killed at temperatures greater than 140°F (60°C).

2. pH. Legionella can tolerate an acid environment down to pH of 2.0.

3. The presence of nutrients.

4. The presence of other micro-organisms. Under normal conditions, protozoa and amoebas feed on Legionella bacteria thus controlling the population.

A.4 Stages

Stage 1: Colonization

Prevention of colonization is very difficult, since the Legionella bacteria occurs naturally in most water sources.

Stage 2: Amplification

Amplification occurs in the presence of nutrients such as algae, slime and sludge and in the right environmental conditions. Although normally protozoa feed on Legionella, the more virulent forms of the bacteria multiply within the protozoa.

Stage 3: Dissemination:

This occurs primarily by aerosolization in cooling towers, evaporative condensers, humidifiers, cooling coil condensate drain pans, traps, respiratory therapy devices, whirlpools, shower heads, misting machines, and, nebulizers. Aerosols may also be generated by running tap water in wash basins, sinks and baths.

Stage 4: Transmission

This occurs primarily through air. It is believed that the aerosol can travel 500 m and still induce infection in susceptible persons. Conditions that are conducive to transmission of Legionella bacteria include:

1. Relative humidity in the 60-90% range
2. Exposure to sunlight and winds
3. Droplet size: smaller droplets have higher terminal velocities and remain suspended in air for longer time. Hence, they travel further and pass more deeply into the lungs when inhaled as compared to larger droplets. However, evaporation of large droplets creates smaller droplets with higher concentrations of bacteria.

Outside air drawn into HVAC systems is often found to contain air discharged from nearby cooling towers. In such conditions, the bacteria can be transmitted into the air distribution system, triggering an outbreak of Legionella.

Stage 5: Inhalation by Susceptible Host

By inhalation, the small droplets carrying the bacteria are deposited deeply in the lower respiratory tract. Exposure time does not have to be long for the disease to occur. Cases of Legionella occurred simply by walking near a building having a contaminated cooling tower, and by washing without showering after a brief exposure.

Survival of the bacteria in aerosols is reported to be at a maximum at 65% RH. The risk of acquiring infection by L. increases with the number of bacteria deeply inhaled and therefore, with the proliferation of these bacteria in the water source and the extent to which they are dispersed in aerosols.

Stage 6: Intracellular Multiplication

If the dose received overwhelms the susceptible host's natural defense mechanisms, the bacteria multipies intracellularly and infection occurs. Although previously healthy people may contract the disease, the persons most at risk are those who have a preexisting condition that weakens their immune system. Smokers and heavy drinkers are also at a higher risk.

Stage 7: Diagnosis

This is the last stage in recognition of a case of Legionella Disease. With proper treatment methods, fatalities occur in a very small percentage of the cases.