



Technical Bulletin

Chemical Water Treatment Recommendations For Reduction of Risks Associated with Legionella in Open Recirculating Cooling Water Systems

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FORWARD

This document provides chemical water treatment recommendations intended to reduce the risk of illness associated with Legionella bacteria in open recirculating cooling water systems treated by BetzDearborn. For background information on Legionella bacteria and Legionellosis see BetzDearborn Capability Profile (CP125) "Information About Legionnaires Disease That May Help Minimize Risk".

These guidelines are based on the aggressive use of halogens (chlorine and bromine) supplemented with biodispersants and nonoxidizing biocides. Use of nonoxidizers is particularly important when oxidizers cannot be fed continuously (the preferred application mode). Nonoxidizers will also enhance biocontrol in systems subject to biofouling, such as those experiencing process contamination or which use effluent water for makeup.

BetzDearborn's recommendations are based primarily on information published by the Cooling Technology Institute (CTI). The CTI document, "Legionellosis - Guideline: Best Practices for Control of Legionella" can be found on the CTI Web site at www.cti.org. The guidance provided in this BetzDearborn document extends the CTI recommendations to accommodate variations in water quality as well as differences in cooling system operations that are not covered in the CTI document. Although it is impossible to anticipate every combination of equipment, water quality and

operating parameters that will be encountered, these guidelines can provide guidance for developing programs for conditions not specifically addressed in the CTI document.

Other sources used in developing these recommendations include documents from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the Occupational Safety and Health Administration (OSHA), and the Centers for Disease Control (CDC). These documents will be of special interest to those attempting to develop Legionella minimization guidelines for water systems other than open recirculating cooling systems.

These recommendations do not take the place of any legally mandated requirement issued by local, state or federal government or their agencies. Use of biocide products should comply with application instructions appearing on the label.

Chemical treatment alone will not be effective in reducing health hazards associated with Legionella bacteria. System design and location, maintenance practices and employee awareness are critical elements of a successful risk reduction program. The intent of this document is to provide recommendations for chemical treatment which, when combined with good system design, sound maintenance practices, and employee awareness, will help minimize the risk of health problems associated with Legionella bacteria.

INTRODUCTION

The following best practices for microbiological control are recommended to maintain clean heat transfer surfaces and to reduce biological hazards from open recirculating cooling systems. Apart from health issues, control of microbiological populations in water systems is essential to prevent biofouling. In cooling systems, biofouling of heat exchange equipment and cooling tower fill reduces heat transfer efficiency and can force unscheduled shutdowns and extended turn-arounds. This can lead to shutdown of cooling systems resulting in loss of building air-conditioning or production losses. Equipment can also be damaged as a result of microbiologically influenced corrosion (MIC) associated with biofouling. Biofouling must be prevented in order for operating units to avoid such events and operate efficiently.

These recommendations will not guarantee the absence of *Legionella* bacteria or any other particular pathogen; nor will these measures prevent illness (e.g. Legionellosis). Nevertheless, we believe implementation of these recommendations will reduce populations of pathogens thereby reducing the risk of associated illness. This is accomplished directly by destruction of planktonic (free-swimming) bacteria, including *Legionella* and indirectly by eliminating conditions favoring *Legionella* amplification (multiplication), i.e., the elimination of biofilms as well as amoebas and other protozoa that feed on biofilms and serve as *Legionella* hosts. Research continues on effective means for control of protozoa cysts that can also harbor and protect *Legionella* bacteria.

While these best practice recommendations focus on biological control, such treatments are only one aspect of *Legionella*/Legionellosis risk minimization. Design, location, operation and maintenance are critical to reducing health risks associated with cooling systems. Further, in addition to mechanical repair and physical cleaning, good maintenance must be understood to require a complete cooling water treatment program that protects against corrosion, scale and deposition and which is compatible with the bio-control measures recommended here.

ROUTINE MONITORING

Evaluate system cleanliness and the effectiveness of microbial control using a combination of visual inspection and monitoring of total heterotrophic bulk water (planktonic) and surface (sessile) microbial populations. System size and cleanliness, the presence or absence of factors that contribute to biofouling, the system's history relative to biofouling, as well as service schedules and manpower availability have to be considered when choosing appropriate monitoring

tools. The frequency with which general microbial monitoring is performed will depend on similar factors including biological loading, microbial growth rates, and equipment susceptibility to fouling. In some systems, weekly checks of biological activity levels can suffice while in other systems and under certain conditions, daily monitoring may be required.

Check the entire tower for evidence of gross biofouling. Pay particular attention to tower deck and fill. Inspect the mist eliminator section of the tower for biological deposits. Collect suspected biological deposits for microscopic examination which can confirm biological content and detect amoebas and ciliated protozoans. While standardized methods for quantifying these organisms in deposits may not exist, examination of deposits by a trained microscopist will provide valuable information on system cleanliness and associated health risk since some protozoans serve as host organisms for *Legionella* bacteria allowing amplification of *Legionella* to high levels. Large numbers of these organisms in deposits represent an increased risk for multiplication of *Legionella* and consequently, increase the risk of Legionnaires' disease for susceptible individuals. Contact the BetzDearborn MB Customer Services lab for guidance on deposit sample collection and shipping.

Use dipslides, PetriFilm, or other culturing techniques to quantify total aerobic heterotrophic bacteria populations in bulk water and on surfaces. Although a direct correlation between bulk water total aerobic bacteria levels and the presence of *Legionella* has not been established, bulk water monitoring results do have limited value as indicators of system cleanliness especially when used in combination with other techniques. Sterile or low bulk water counts do not guarantee clean surfaces or an absence of biofilms, but inability to keep bulk water counts under control can be a strong indicator of an underlying biofouling problem. Sessile monitoring provides a more direct indication of surface cleanliness, and consequently, the presence or absence of significant biofilm populations.

ATP-based biomonitoring is the preferred monitoring technique since it eliminates the 2-day wait for results imposed by incubation requirements of culture-based methods. ATP-based monitoring also provides more complete information on biological activity since it detects the full range of microbes (including protozoans) present in the cooling system, not just bacteria.

ATP-based results will not always correlate to culture-based results for total aerobic bacteria whether from bulk water or surface samples. ATP-based biomonitoring responds to changes in bioactivity and biomass, which go beyond simple numbers of culturable aerobic bacteria (generally only a small subset of the total

microbial population). See Web Atlas - Cooling/Spectrus/ Biomonitoring/ Bioscan for information on ATP-based procedures for bulk water as well as sessile monitoring.

MONITORING FOR LEGIONELLA

To date, most professional and government agencies that have issued Legionella position statements and guidelines DO NOT recommend testing for Legionella bacteria on a routine basis. Legionella monitoring is only recommended under a limited set of circumstances. The reasons for not routinely testing for Legionella derive from difficulties in interpreting Legionella test results and difficulties using test results as a basis for control (as noted in the following points).

- An infectious dose level for Legionella has not been established and in any case, given variations in strain virulence and wide differences in individual susceptibility, the concept of a fixed infectious dose level may be misleading. Since no "danger" level can be assigned, no one level of the organism can be taken as "safe".
- Legionella may be "non-detectable" in bulk water samples collected on one day but detectable the next as they are released from biofilms or host life forms associated with these films. Also, Legionella bacteria are reported to be capable of rapidly recolonizing previously cleaned systems.
- Simple detection of the organism in a cooling system does not automatically mean there is a disease risk since not all Legionella species are associated with Legionellosis.
- Culture-based techniques used by testing labs to quantify Legionella bacteria have a 10 to 14-day turnaround for results. This period is too long for Legionella monitoring to serve as an effective tool for treatment control.

Various studies have shown that some 40 to 60% of cooling towers tested contained Legionella bacteria. It is therefore best to assume that any given system can harbor the organism and routine microbiological control practices should be implemented to minimize the risk of Legionella amplification and associated disease.

When to test for Legionella

Testing for Legionella is recommended in the event of an outbreak (to identify potential sources of the organism) and to evaluate the effectiveness of subsequent disinfection procedures. If testing for Legionella is to be conducted, contact the laboratory for sampling and shipping instructions. See the BetzDearborn

Capability Profile (CP125), "Information About Legionnaires Disease That May Help Minimize Risk" for recommended Legionella testing facilities. OSHA disinfection protocols require bulk water levels of Legionella to be "non-detectable" immediately after disinfection. During the subsequent 6-month required sampling period, Legionella levels should be <10 CFU/ml.

If Legionella testing is performed, also perform total aerobic heterotrophic bacteria counts or ATP-based biomonitoring using bulk water and surface samples at the time of sampling for Legionella. Collect deposit samples for microscopic detection of higher life forms. Direct linkage between high total aerobic bacteria counts and Legionella has not been established. The intent of multiple analyses is to provide a more complete context for understanding the results of Legionella testing as discussed below.

Collect water samples from several locations throughout the system, (e.g., hot return water, water that has just passed through the tower fill [before it reaches the basin] and, if available, from sample taps on exchangers remote from the cooling tower). Also collect samples of makeup water. Corrosion coupons can be sampled to provide information on biofilm levels. Where evident, collect deposits from the basin walls, tower fill and distribution deck. Have a trained microscopist examine deposit samples for the presence of amoeboid and ciliated protozoa. Data from all sample sources can be used to interpret Legionella test results as in the following examples.

1. A very low or non-detectable bulk water Legionella count (e.g., <1 CFU/ml) and a non-detectable population of amoebas/protozoa together with low biofilm counts (low sessile bacteria numbers) are consistent with a clean, well-maintained system and a low risk to health.
2. A low bulk water Legionella count (e.g., <10 CFU/ml) along with low numbers of higher life forms in deposits, but with high biofilm counts may indicate a low immediate health risk but suggests the potential for future problems if steps are not taken to reduce biofilm levels. Since amoebas and protozoa that promote Legionella amplification graze on bacteria in biofilms, significant biofilm levels can set the stage for future dangerous levels of Legionella bacteria.
3. A low bulk water Legionella count associated with numerous higher life forms indicates a strong potential for amplification, and the low Legionella count cannot therefore be interpreted to indicate a system with a low risk to health.

The following results are recommended targets during routine treatment of cooling water systems:

Parameter	Dipslides ¹	Agar Pour Plates or PetriFilm ¹	Bioscan (RLU) ²	Microscopic Exam ³
Planktonic Counts (Bulk Water)	<10 ⁴ CFU/ml	<10 ⁴ CFU/ml	<40	Not Applicable
Sessile Counts (Surfaces)	<10 ⁵ CFU/cm ²	<10 ⁵ CFUcm ²	<400	Not Applicable
Deposits ⁴	Not Applicable	Not Applicable	Not Applicable	No higher life forms

- 1 - Results are as Colony Forming Units (of Total Aerobic Heterotrophic Bacteria) per milliliter.
- 2 - Bioscan ATP biomonitoring results are as Relative Light Units. Bioscan results should not be compared to results from other ATP biomonitoring systems. Coefficient of Variation for Bioscan results is $\pm 16\%$.
- 3 - Examination of deposit samples for the presence of protozoa requires a trained microscopist and specialized equipment.
- 4 - Bioscan or culture-based methods applied to deposits can provide a qualitative indication of biological content; e.g., $>10E7$ CFU/g of deposit or RLU values $>4,000/1g$ of deposit suspended in 9 ml sterile water suggest a significant biological component in the deposit.

ROUTINE TREATMENT

Continuous Chlorination (pH <8.5; no ammonia contamination)

At the present time, chlorine gas and bleach (10 to 12.5% by weight as NaOCl) are generally the most cost-effective disinfectants for cooling water.

1. For relatively clean systems using chlorinated or potable quality makeup water, feed halogen continuously and maintain a free chlorine residual of 0.5 to 1.0 ppm as Cl₂.
2. For other systems that use:
 - unchlorinated surface or well water makeup
 - wastewater or reclaimed water makeup

or

 - that have process leaks
 - are prone to heavy biofouling

feed halogen continuously and maintain a free residual of 1.0 to 2.0 ppm as Cl₂

3. When starting up systems or when servicing new or unfamiliar systems, monitor halogen residuals at several points in the system to ensure uniform distribution. Test for residuals in samples of cooling tower basin water, supply water, recirculating water at a point remote from the tower, hot return water at the tower, water that has just passed through the fill (before it reaches the basin) and

cooling tower blowdown. Once halogen residuals are known to be well distributed, rely primarily on hot return and "tower fill" water samples.

4. Continuously chlorinated systems that discharge directly to rivers, lakes or streams will require dechlorination. Feed 2.5 ppm of Spectrus DT1402 or 5.0 ppm Spectrus DT1403 for each 1 ppm of total residual halogen (as Cl₂) to be dechlorinated.
5. Feed a biodispersant. Use Spectrus BD1501 in systems prone to hydrocarbon leaks. In all others, use Spectrus BD1500 (aka BD151). Apply product continuously at 5 to 10 ppm based on system blowdown or shot-feed daily at 15 to 25 ppm based on system volume.
6. Continuous halogen treatment programs may require periodic use of nonoxidizing biocides. Nonoxidizers are especially recommended for systems with:
 - open distribution decks
 - high efficiency film fill
 - shell-side heat exchangers
 - wastewater makeup
 - frequent process contamination
 - heavy algal biofouling
 - general biofouling
 - sulfate reducing bacteria (SRB)
7. Select nonoxidizing biocides based on performance in toxicant evaluations. Typically, these tests evaluate products against aerobic heterotrophic bacteria. They can be conducted by the BetzDearborn Microbiological Customer Service Laboratory or performed on-site.
8. Nonoxidizers should be halogen compatible. Most BetzDearborn biocide active ingredients are halogen compatible. Only Methylene-Bis-Thiocyanate and Bromo-Nitro-Styrene (found in Spectrus NX1103 (NX104), Spectrus NX1108, and Spectrus NX118) are known to be degraded by halogens.
9. Typically, nonoxidizers should be shot-fed to system volume at 50 to 100 ppm. Nonoxidizing biocides must carry appropriate EPA approved end-use label claims, and dosages must comply with label limits. Use molybdate or another measurable salt to accurately determine system volume.
10. Reapply nonoxidizing biocides as dictated by the results of biomonitoring.

Intermittent Chlorination (pH <7.8; no ammonia contamination)

Continuous application of chlorine is preferred for Legionella risk minimization; however, if a system is too large or if it discharges directly to a river, lake, or stream, intermittent chlorination may be necessary. In addition, halogen donor products are frequently applied on an intermittent, shock-dose basis.

1. As a minimum control program for relatively clean systems using chlorinated or potable quality makeup water, establish a free halogen residual of 1.0 ppm as Cl₂ and hold this residual for 1 hour each day.
2. For other systems that use:
 - unchlorinated surface or well water makeup
 - wastewater or reclaimed water makeupor
 - that have process leaks
 - are prone to heavy biofoulingestablish a free halogen residual of 2.0 ppm as Cl₂ for 2 hours each day as a minimum control program.
3. When starting up systems or when servicing new or unfamiliar systems, monitor halogen residuals at several points in the system to ensure uniform and adequate distribution during the feed period. Extend the feed period if effective halogen residuals are not distributed throughout the system. Test for residuals in samples of tower basin water, supply water, recirculating water at a point remote from the tower, hot return water at the tower, water that has just passed through the fill (before it reaches the basin) and tower blowdown. Once halogen residuals are known to be well distributed, rely primarily on hot return and "tower fill" water samples.
4. Bulk water and sessile counts along with microscopic examination of deposit samples will be necessary to ensure that the concentration and duration of chlorine residuals are adequate.
5. Feed a biodispersant. Use Spectrus BD1501 in systems prone to hydrocarbon leaks. In all others use Spectrus BD1500 (aka BD151). Shot-feed product to system volume at 15 to 25 ppm approximately 30 minutes prior to the start of halogenation.
6. Discharge streams going directly to rivers, lakes or streams will require dechlorination. Feed 2.5 ppm of Spectrus DT1402 or 5.0 ppm Spectrus DT1403 for each 1 ppm of total residual halogen (as Cl₂) to be dechlorinated.

7. Nonoxidizing biocides are critical to the cleanliness of systems treated intermittently with halogens. In such systems, nonoxidizers may have to be applied more frequently and at higher dosages than in systems that are continuously halogenated. Nonoxidizers are especially recommended for intermittently halogenated systems that have:

- open distribution decks
- high efficiency film fill
- shell-side heat exchangers
- wastewater makeup
- frequent process contamination
- heavy algal biofouling
- general biofouling
- sulfate reducing bacteria (SRB)

8. Select nonoxidizing biocides based on performance in toxicant evaluations. Typically, these tests evaluate products against aerobic heterotrophic bacteria. They can be conducted by the BetzDearborn Microbiological Customer Service Laboratory or performed on-site.

9. Nonoxidizers should be halogen compatible. Most BetzDearborn biocide active ingredients are halogen compatible. Only Methylene-Bis-Thiocyanate and Bromo-Nitro-Styrene [found in Spectrus NX1103 (NX104), Spectrus NX1108, and Spectrus NX118] are known to be degraded by halogens.

10. Typically, nonoxidizers should be shot-fed to the system volume at 50 to 100 ppm. Nonoxidizing biocides must carry appropriate EPA-approved end-use label claims, and dosages must comply with label limits. Use molybdate or other measurable salt to accurately determine system volume.

11. Reapply nonoxidizing biocides as dictated by the results of biomonitoring.

Use of Halogen Donor Products

Halogen residuals can be generated using hydantoin [Spectrus OX103, Spectrus OX1200 (aka OX107)] or isocyanurate (Spectrus OX101, OX105) halogen donor products. Such products release active bromine and/or chlorine on contact with water. Typically, these products are best suited for systems that use good quality makeup water and which are not subject to process contamination.

As with chlorine gas or liquid chlorine bleach, feeding these products to generate a continuous halogen residual is preferred for Legionella risk minimization.

If a system is too large, or if it discharges directly to a river, lake, or stream, intermittent feed may be necessary. Nonoxidizing biocides are critical to the cleanliness of systems treated intermittently with halogen donor products.

Follow product label directions and target halogen residuals as noted below.

Halogen donor products release halogens in a controlled fashion. Such products - especially hydantoin types [Spectrus OX103, OX1200 (OX107)] - are designed to generate total halogen residuals and may require extremely high feedrates to achieve free halogen residuals. Further, the HACH Water Analysis Handbook specifies use of the DPD total chlorine test method for measuring bromine residuals (regardless of source). The DPD free chlorine test under-reports bromine residuals. The combined effect of controlled release and test sensitivity makes "total residual" a better indicator of the full germicidal residual generated by bromo-hydantoin donor products. In most applications therefore, feed hydantoin donors according to label directions (see table below) and target total residuals 2 to 3 times the free residuals recommended above for chlorine fed continuously or intermittently. Target free residuals (using the Free Residual Chlorine test) only if such total residuals fail to provide adequate biocontrol.

Isocyanurate (also called triazine-S-trione) products such as Spectrus OX101, and OX105, are primarily chlorine donors that release halogen much more quickly than hydantoin. Most of the total available halogen residual generated by these products will be measurable as free chlorine residual. When using isocyanurate-type products, follow label directions and target free chlorine residuals as for chlorine gas or bleach applied continuously or intermittently.

Halogenation of Alkaline Systems

Chlorine disinfection rates may be adversely affected by alkaline pH conditions. These effects are more likely to be significant in systems that are intermittently chlorinated as opposed to those that are continuously treated.

- In continuously chlorinated systems, effects on chlorine of pH <8.5 can be largely offset by operating at the upper end of the free residual chlorine ranges recommended above. Consider bromine for continuously chlorinated systems that operate at pH ≥8.5.
- In intermittently treated systems, consider bromine for waters having pH ≥7.8.
- Bromine can be applied by feeding an active bromine donor such as Spectrus OX103, or

OX1200 (OX107) or by feeding liquid bromide products [Spectrus OX1201 (OX109)] which require activation by chlorine.

- As a minimum, when feeding a bromide product, add bromide at a ratio of 1 mole bromide per 4 moles of available chlorine (i.e. 0.9 pounds of Spectrus OX1201 [OX109] per 1 pound of available chlorine) being fed to the system. This will produce a halogen stream consisting of 75% HOCl and 25% HOBr. Up to 3.6 pounds of Spectrus OX1201 (OX109) per 1 pound of available chlorine (generates 100% HOBr) may be required in systems with pH >8.5.
- When feeding bromide products, target total halogen residuals comparable to the free residual halogen levels recommended above for chlorine gas or bleach fed continuously or intermittently to "neutral" pH systems.
- Certain hydantoin-type halogen donor products release bromine in a controlled fashion. Products such as Spectrus OX103, OX1200 (OX107) are designed to generate total halogen residuals and may require extremely high feedrates to achieve free halogen residuals. Further, the HACH Water Analysis Handbook specifies use of the DPD total chlorine test method for measuring bromine residuals (regardless of source). The DPD free chlorine test under-reports bromine residuals. The combined effect of controlled release and test sensitivity makes "total residual" a better indicator of the full germicidal residual generated by bromine donor products. In most applications therefore, feed bromo-hydantoin donors according to label directions and target total residuals 2 to 3 times the free residuals recommended for chlorine fed continuously or intermittently. Target free residuals (using the Free Residual Chlorine test) only if such total residuals fail to provide adequate biocontrol.

Halogenation of Ammonia Contaminated Systems

Chlorine combines with ammonia and other amine-type species to form chloramines. Disinfection with chloramines is slower than with free chlorine species (HOCl and OCl⁻). Feeding 8 to 13 ppm of chlorine (as Cl₂) for each 1 ppm of ammonia is required to destroy ammonia and achieve a free chlorine residual (breakpoint chlorination). In the presence of high levels of ammonia contamination, breakpoint chlorination may not be practical. For Legionella risk minimization in ammonia contaminated systems, apply chlorine to produce chloramine residuals (i.e. combined residuals measured as Total Residual Chlorine) that are 10 times the recommended free chlorine residual levels.

Label Guidelines for Solid Halogen Donor Products

All Dosages based on application to system volume

<p>Products: Spectrus OX103, OX1200 (OX107) Type: Bromo, Chloro-Hydantoin. OX103: ~1" tablet; OX1200 (OX107): granular.</p> <p style="text-align: center;">INITIAL DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>24 to 72 ppm</td><td>13 to 40 ppm</td></tr></tbody></table> <p>When system is fouled, repeat initial dose until 1-3 ppm Br₂ (i.e. 0.4 - 1.3 ppm as Cl₂) is established for at least 4 hours.</p> <p style="text-align: center;">SUBSEQUENT DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>12 to 36 ppm</td><td>6.5 to 20 ppm</td></tr></tbody></table> <p>When control is evident, add 12 to 36 ppm as product. Repeat as needed to maintain 1 to 3 ppm Br₂ (i.e. 0.4 to 1.3 ppm as Cl₂) for at least 4 hours.</p>	as product	as Total Av. Cl₂	24 to 72 ppm	13 to 40 ppm	as product	as Total Av. Cl₂	12 to 36 ppm	6.5 to 20 ppm
as product	as Total Av. Cl₂							
24 to 72 ppm	13 to 40 ppm							
as product	as Total Av. Cl₂							
12 to 36 ppm	6.5 to 20 ppm							
<p>Products: Spectrus OX1202 Type: DiChloro-Hydantoin in briquette form (~1.5").</p> <p style="text-align: center;">INITIAL DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>12 to 120 ppm</td><td>8 to 82 ppm</td></tr></tbody></table> <p>When system is fouled, repeat initial dose until control is achieved is established for at least 4 hours.</p> <p style="text-align: center;">SUBSEQUENT DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>12 to 90 ppm as product</td><td>8 to 61 ppm</td></tr></tbody></table> <p>When control is evident, add 12 to 90 ppm as product every 3 days or as needed for control.</p>	as product	as Total Av. Cl₂	12 to 120 ppm	8 to 82 ppm	as product	as Total Av. Cl₂	12 to 90 ppm as product	8 to 61 ppm
as product	as Total Av. Cl₂							
12 to 120 ppm	8 to 82 ppm							
as product	as Total Av. Cl₂							
12 to 90 ppm as product	8 to 61 ppm							
<p>Products: Spectrus OX105 Type: TriChloro-Isocyanurate in puck form (~3") w/small amount NaBr.</p> <p style="text-align: center;">INITIAL DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>12 to 60 ppm</td><td>9.5 to 47.5 ppm</td></tr></tbody></table> <p>When system is fouled, repeat initial dose until total available halogen residual of 0.5 to 10.0 ppm as Cl₂ is achieved.</p> <p style="text-align: center;">SUBSEQUENT DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>2.4 to 12 ppm</td><td>2.0 to 9.5</td></tr></tbody></table> <p>When control is evident, add 2.4 to 12 ppm as product to achieve total available halogen residual of 0.5 to 1.0 ppm as Cl₂. Repeat periodically, as needed to maintain control.</p>	as product	as Total Av. Cl₂	12 to 60 ppm	9.5 to 47.5 ppm	as product	as Total Av. Cl₂	2.4 to 12 ppm	2.0 to 9.5
as product	as Total Av. Cl₂							
12 to 60 ppm	9.5 to 47.5 ppm							
as product	as Total Av. Cl₂							
2.4 to 12 ppm	2.0 to 9.5							
<p>Products: Spectrus OX101 Type: DiChloro-Isocyanurate in powder form.</p> <p style="text-align: center;">INITIAL DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>12 to 180</td><td>6.6 to 99</td></tr></tbody></table> <p>When system is fouled, repeat initial dose until control is achieved.</p> <p style="text-align: center;">SUBSEQUENT DOSE</p> <table><tbody><tr><td>as product</td><td>as Total Av. Cl₂</td></tr><tr><td>6 to 120</td><td>3.3 to 66</td></tr></tbody></table> <p>When control is evident, add 6 to 120 ppm as product daily or as needed for control.</p>	as product	as Total Av. Cl₂	12 to 180	6.6 to 99	as product	as Total Av. Cl₂	6 to 120	3.3 to 66
as product	as Total Av. Cl₂							
12 to 180	6.6 to 99							
as product	as Total Av. Cl₂							
6 to 120	3.3 to 66							

If breakpoint chlorination is not practical, or if chloramines do not provide adequate biocontrol, consider use of bromine in ammonia contaminated systems. Bromine does not form a stable compound with ammonia and may be used in place of breakpoint chlorination or to replace chloramines in ammonia contaminated systems. Bromine can be applied by feeding active bromine donors such as Spectrus OX103, or OX1200 (OX107) or by feeding liquid bromide prod-

ucts (Spectrus OX1201 [OX109]) which require activation by chlorine.

Feed bromide at a ratio of 1 mole bromide per 2 moles of available chlorine (1.8 pounds of Spectrus OX1201 [OX109] per 1 pound of available chlorine) applied to the system. This will produce a halogen stream consisting of 50% HOCl and 50% HOBr. This ratio of bromide to chlorine is a mid-range value and represents a starting point for optimization of biocontrol

with bromide. The mole ratio of bromide to chlorine necessary for good biocontrol can be as low as 1:4 (0.9 pounds of Spectrus OX1201 [OX109] per 1 pound of available chlorine) applied to the system or as high as 1:1 (3.6 pounds of Spectrus OX1201 [OX109] per 1 pound of available chlorine).

When feeding bromide products to ammonia contaminated systems, target total halogen residuals that are 2 times the free residual halogen levels recommended above for chlorine fed continuously or intermittently to systems that are not contaminated with ammonia.

Certain hydantoin-type halogen donor products release bromine in a controlled fashion. Products such as Spectrus OX103, OX1200 (OX107) are designed to generate total halogen residuals and may require extremely high feedrates to achieve free halogen residuals. Further, the HACH Water Analysis Handbook specifies use of the DPD total chlorine test method for measuring bromine residuals (regardless of source). The DPD free chlorine test under-reports bromine residuals. The combined effect of controlled release and test sensitivity makes "total residual" a better indicator of the full germicidal residual generated by bromine donor products. In most applications therefore, feed bromo-hydantoin donors according to label directions and target total residuals 2 to 3 times the free residuals recommended for chlorine fed continuously or intermittently to non-ammonia contaminated systems. Target free residuals (using the Free Residual Chlorine test) only if such total residuals fail to provide adequate biocontrol.

Sole Use of Nonoxidizing Biocides

Sole use of nonoxidizing biocides whether applied singly or in combination, is not recommended for minimization of Legionella-associated risks. Such programs may be adequate to protect heat exchange equipment and ensure efficient heat transfer, but they do not provide the best protection against the risk of Legionellosis.

ROUTINE DISINFECTION

Hyperchlorination

Periodically disinfect systems on-line using high levels of halogen (hyperchlorination) for brief periods. Perform such routine on-line disinfection at least quarterly.

A monthly hyperchlorination schedule is recommended for systems with:

- Process leaks
- Heavy biofouling of any kind
- Reclaimed water or wastewater as makeup

Or for systems where:

- Total aerobic bacteria counts regularly exceed 100,000 CFU/ml
- Bioscan results regularly exceed 400 RLU
- Legionella tests results show ≥ 100 CFU/ml

Periodic hyperchlorination will help discourage development of large populations of Legionella and their host organisms. Consequently, periodic hyperchlorination may eliminate the need for conducting more complicated off-line emergency disinfection protocols.

Cooling systems that are to be taken out of service should be hyperchlorinated and then drained before being shut down. Similarly, hyperchlorinate before starting up out-of-service equipment. If systems were left flooded when taken out of service, do not operate fans before the hyperchlorination procedure is complete.

Hyperchlorination Procedure

1. Before beginning hyperchlorination, turn off tower fans to avoid blowing aerosol droplets into the surrounding area.
2. If operations will not allow fans to be shut down prior to hyperchlorination, close building air intakes in the vicinity of the tower (especially those downwind) and charge the system with 50 to 100 ppm of a fast-acting non-oxidizing biocide such as Spectrus NX1102 (NX108).
3. If fans cannot be shut down, monitor solids at the start of hyperchlorination. During hyperchlorination, increase and adjust blowdown to minimize solids buildup and the possible aerosolization of sloughed biofilm material, which may harbor Legionella bacteria.
4. Charge the system with supplemental halogen stable corrosion and deposit control agents (Dianodic PLUS treatment programs) and feed to maintain target residuals during hyperchlorination.
5. Feed chlorine gas, liquid chlorine bleach, or isocyanurate-based chlorine donor products to establish and hold a continuous free halogen residual of 5 ppm as Cl_2 for at least 6 hours.
6. If liquid bromide is routinely used because of alkaline system pH, increase the bromide feed in proportion to increased chlorine gas or bleach feed. Establish and hold a total halogen residual (measured as Cl_2) of 5 ppm for at least 6 hours.
7. If bromide is routinely used because of ammonia contamination, increase the bromide feed in pro-

portion to increased chlorine gas or bleach feed. Establish and hold total halogen residuals (measured as Cl₂) of 10 ppm for at least 6 hours.

8. If bromo-hydantoin products are routinely used, apply according to label directions. An initial dose of approximately 20 to 30 ppm as product may be needed to establish and hold a total halogen residual (measured as Cl₂) of 10 - 15 ppm for at least 6 hours.
9. Near the end of the hyperchlorination period and before the fans are turned back on, open blowdown completely to flush out loosened biological material and other debris.
10. Discharge streams going directly to rivers, lakes or streams may require dechlorination. Feed 2.5 ppm of Spectrus DT1402 or 5.0 ppm Spectrus DT1403 for each 1 ppm of total residual halogen (as Cl₂) to be dechlorinated.
11. Adjust halogen and other chemical feeds as needed to accommodate increased blowdown and maintain desired residuals.
12. When flushing is complete, reduce blowdown and adjust halogen and chemical inhibitor feeds to reestablish normal water chemistry and treatment residuals.

TOWER WOOD DELIGNIFICATION

High free chlorine residuals in combination with high alkalinity can dissolve lignin, the binder that holds cellulose fibers together in wood. When lignin is solubilized, cellulose fibers can be liberated. These fibers may be noticed as they accumulate on pump screens in the cooling system. Long term operation (i.e. months) under continuous delignifying conditions can reduce the size of wood components and result in the loss of mechanical strength. Typical conditions for delignification are exposure to 1 ppm Free Residual Chlorine and a pH of at least 9.0. Brief exposure to high free chlorine residuals is not expected to cause delignification. Delignification is also not a great concern in newly constructed towers because they contain less wood. Delignification may be a concern in older, largely wooden cooling towers. Operating cooling systems that contain such towers at slightly lower pH values or with slightly lower chlorine residuals will help reduce delignification.

EMERGENCY DISINFECTION

The following emergency disinfection procedure is based on OSHA recommendations. This procedure may require modification based on system volume,

water availability and wastewater treatment capabilities.

Conduct emergency disinfection:

- When very high Legionella counts exist (i.e. >1000 CFU/ml).
- If cases of Legionnaires disease are known or suspected and may be associated with the cooling tower.
- When very high total MB counts (>100,000) reappear within 24 hours of a routine disinfection (hyperchlorination).

Emergency Disinfection Procedure

1. Remove heat load from the cooling system.
2. Shut off fans associated with the cooling equipment.
3. Shut off the system blowdown. Keep makeup water valves open and operating.
4. Close building air intake vents in the vicinity of the cooling tower (especially those downwind) until after the cleaning procedure is complete.
5. Continue to operate the recirculating water pumps.
6. Charge the system with halogen stable corrosion and deposit control agents (Dianodic PLUS treatment programs).
7. Add a fast-release, oxidizing biocide (e.g., chlorine gas, liquid chlorine bleach, calcium hypochlorite, chloro-isocyanurates) corresponding to 25 to 50 ppm of free residual chlorine.
8. Add an appropriate biodispersant such as Spectrus BD1500 (BD 151) at 25 to 50 ppm. An antifoam (FoamTrol™ AF1440) may be required.
9. Maintain a 10 ppm free residual chlorine for 24 hours. Add chlorine as needed to maintain the 10 ppm residual.
10. Monitor the system pH. Since the rate of chlorine disinfection slows at higher pH values, feed acid or reduce cycles to achieve and maintain a pH of <8.0 (target pH range of 7.0 to 7.5).
11. Drain the system to a sanitary sewer. If the facility has a discharge permit, dechlorination by chemical addition will be needed. Feed 2.5 ppm of Spectrus DT1402 or 5.0 ppm Spectrus DT1403 for each 1 ppm of total residual halogen (as Cl₂) to be discharged.
12. Refill the system and repeat steps 1 through 11.

13. Inspect after the second drain-off. If biofilm is evident, repeat the procedure.
14. When no biofilm is present, mechanically clean fill, tower supports, cell partitions, and sump. Workers engaged in tower cleaning should wear eye protection as well as half face respirators with HEPA filters (or other filters capable of removing 1-micron particles).
15. Refill and recharge the system with chlorine to achieve a 10-ppm free chlorine residual. Hold this residual for 1 hour and then drain and flush the system until free of turbidity.
16. Refill the system with water; charge with corrosion and deposit control chemicals, re-establish normal biocontrol residuals and put the cooling tower back in service.

PERSONAL PROTECTIVE EQUIPMENT

When there is potential for significant exposure to Legionella, (e.g. system not treated in accordance with the CTI Guideline) use either a half-mask, full facepiece or disposable respirator equipped with P100 filters (i.e., HEPA filters). Refer to Section III: Chapter 7 of the OSHA Technical Manual for a discussion of relative risks associated with various levels of Legionella infestation.

OSHA's Technical Manual Chapter 7 recommends wearing a half-mask respirator equipped with a HEPA or similar type filter capable of collecting one micron particles during the examination of operating cooling systems suspected of being contaminated with Legionella. The same OSHA manual recommends a Tyvek-type suit with hood, protective gloves, and a properly fitted respirator with a HEPA filter (as described earlier) when performing cleaning and maintenance on cooling towers that require emergency disinfection.

In the case of the half-mask or full facepiece respirator, change out the cartridge at the end of the shift. When using a disposable respirator, discard it at the end of the shift. If the filter cartridge or the disposable respirator becomes damaged, soiled, or if breathing becomes difficult at any time during the shift, leave the contaminated area and replace the filter cartridges or disposable respirator. You should refer to your organizations' safety manual or industrial hygienist for additional information regarding the use and maintenance

of respirators, as well as the medical surveillance, fit testing and training requirements.

RECORD KEEPING

All activities related to Legionella risk reduction efforts should be documented as part of a service report and communicated to appropriate plant personnel, including health and safety officers. Where relevant, note date, time, and point of sample collection or date and time of specific preventative activities. Such documentation should include results of:

- visual inspections
- bulk water monitoring
- sessile monitoring
- microscopic analysis of deposits
- Legionella monitoring
- halogen residual testing
- biocide testing (toxicant evaluations)

as well as:

- additions of water treatment chemicals (especially nonoxidizers and biodispersants); note date, time, and quantity added
- hyperhalogenation for routine disinfection (note date performed, residual achieved and time held)
- tower maintenance activities (i.e., cleaning and mechanical repairs)
- recommendations to plant personnel in aid of Legionella risk reduction
- meetings with plant personnel on Legionella risk reduction efforts

Establishing a pattern of responsible water treatment, employee awareness, and good communication on this topic will be invaluable in the event that a cooling system is linked to illness caused by Legionella bacteria.