GE
Water & Process Technologies

Technical Bulletin

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

Introduction

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 GE Water & Process Technologies. For background information on Legionella bacteria and Legionellosis see GE Capability Profile (CP128) "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.

The GE 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 GE 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), the Centers for Disease Control (CDC) and Great Britain's Health and Safety Executive (HSE). 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 requirements issued by local, state or federal governments 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 that, when combined with good system design, sound maintenance practices and employee awareness, will help minimize the risk of health problems associated with Legionella bacteria.

The following best practices for microbiological control are recommended to maintain clean heat transfer surfaces and reduce biological hazards in 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

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equipment and cooling tower fill reduces heat transfer efficiency and can force unscheduled shutdowns and extended turnarounds. This can lead to shutdowns of cooling systems, resulting in the loss of building air-conditioning or production. 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 the 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, operating practices 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 biocontrol 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 the 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 risks. This is important since some protozoans serve as host organisms for Legionella bacteria, allowing amplification of Legionella to high levels. Large numbers of these organisms in deposits may represent an increased risk for multiplication of Legionella and, consequently, increase the risk of Legionnaires' disease for susceptible individuals. Contact the GE MB Customer Services Laboratory 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.

Adenosine triphosphate (ATP)-based biomonitoring is the preferred monitoring technique since it eliminates the two-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).

The results in Table 1 are recommended targets during routine treatment of cooling water systems.

Table 1

Parameter	Dip-slides[1]	Agar Pour Plates or PetriFilm[1]	BIOSCAN* (RLU)[2]	Micro-scopic Exam[3]
Planktonic Counts (Bulk Water)	$<10^4$ CFU/mL	$<10^4$ CFU/mL	<40/mL	Not Applicable
Sessile Counts (Surfaces)	$<10^5$ CFU/cm^2	$<10^5$ CFU/cm^2	<400/cm^2	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 ± 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 relative light unit (RLU) values >4,000/mL or 1.0 g 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 (mg/L) as Cl_2.
2. For other systems that:
   - Use nonchlorinated surface or well water makeup
   - Use wastewater or reclaimed water makeup
   - Have process leaks
   - Are prone to heavy biofouling

   feed halogen continuously and maintain a free residual of 1.0 to 2.0 ppm (mg/L) as Cl_2.
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 though the fill (before it reaches the basin; i.e., "tower fill") 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 (mg/L) of Spectrus* DT1402 or 5.0 ppm (mg/L) Spectrus DT1404 for each 1 ppm (mg/L) of total residual halogen (as Cl_2) to be dechlorinated.
5. Feed a biodispersant. Use Spectrus BD1501 in systems prone to hydrocarbon leaks. In all others, use Spectrus BD1500 (aka BD151) or BD1550. Apply BD1500 continuously at 5 to 10 ppm (mg/L) based on system blowdown or shot-feed daily at 15 to 25 ppm (mg/L) based on system volume. BD1550 may be applied continuously at 10 ppm (mg/L) based upon system blowdown, or shot fed at 35 to 50 ppm (mg/L) based on system volume. Antifoams (e.g., FoamTrol* AF1440) should be on hand for use with biodispersants. When shot-feeding Spectrus BD products, apply approximately 30 minutes prior to the start of halogenation.

Nonoxidizer Biocide Use with Continuous Chlorination

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 or plate and frame heat exchangers

- Wastewater makeup
- Frequent process contamination
- Heavy algae biofouling
- General biofouling
- Sulfate reducing bacteria (SRB)

1. Select nonoxidizing biocides based on performance in toxicant evaluations. Typically, these tests evaluate products against aerobic heterotrophic bacteria. They can be conducted by the GE Microbiological Customer Service Laboratory or performed on-site.
2. Nonoxidizers should be halogen compatible. Most GE biocide active ingredients are halogen compatible. Only methlyene-bis-thiocyanate (found in Spectrus NX1103 and NX104) is known to be degraded by halogens at typical use levels.
3. Typically, nonoxidizers should be shot-fed to system volume at 50 to 100 ppm (mg/L). 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.
4. Reapply nonoxidizing biocides as dictated by the results of biomonitoring.

Intermittent Chlorination (pH <7.8; No Ammonia Contamination) with Chlorine Gas or Bleach

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 only, then intermittent chlorination may be possible. 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 (mg/L) as Cl_2 and hold this residual for one hour each day. The duration of feed and/or level of measured residual halogen should be assessed versus success in controlling system biofouling.
2. For other systems that:
   - Use nonchlorinated surface or well water makeup
   - Use wastewater or reclaimed water makeup
   - Have process leaks
   - Are prone to heavy biofouling

   establish a free halogen residual of 2.0 ppm (mg/L) as Cl_2 for two hours each day as a minimum control program. The duration of feed and/or level of measured residual halogen should be assessed versus success in controlling system biofouling.
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 though the fill 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) or BD1550. Apply BD1500 continuously at 5 to 10 ppm (mg/L) based on system blowdown, or shot-feed daily at 15 to 25 ppm (mg/L) based on system volume. BD1550 may be applied continuously at 10 ppm (mg/L) based upon system blowdown or shot fed at 35 to 50 ppm (mg/L) based on system volume. Antifoams (e.g., FoamTrol AF1440) should be on hand for use with biodispersants. When shot-feeding Spectrus BD products, apply 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 (mg/L) of Spectrus DT1402 or 5.0 ppm (mg/L) Spectrus DT1404 for each 1 ppm (mg/L) of total residual halogen (as Cl_2) to be dechlorinated.

Nonoxidizing Biocide Use with Intermittent Chlorination

1. Nonoxidizing biocides are critical to the cleanliness of systems treated intermittently with halogens and should be made a routine part of

the treatment program. In such systems, nonoxidizers will have to be applied more frequently than in systems that are continuously halogenated. The presence of any of the following elements in systems that are intermittently chlorinated is a further indication that nonoxidizers are required:

- Open distribution decks
- High efficiency film fill
- Shell-side heat exchangers
- Wastewater makeup
- Frequent process contamination
- Heavy algae biofouling
- General biofouling
- Sulfate reducing bacteria (SRB)

2. Select nonoxidizing biocides based on performance in toxicant evaluations. Typically, these tests evaluate products against aerobic heterotrophic bacteria. They can be conducted by the GE Microbiological Customer Service Laboratory or performed on-site.
3. Nonoxidizers should be halogen compatible. Most GE biocide active ingredients are halogen compatible. Only methlyene-bis-thiocyanate (found in Spectrus NX1103 and NX104) is known to be degraded by halogens at typical use levels.
4. Typically, nonoxidizers should be shot-fed to the system volume at 50 to 100 ppm (mg/L). 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.
5. Reapply nonoxidizing biocides as dictated by the results of biomonitoring.

Use of Halogen Donor Products for Routine Treatment

Halogen residuals can be generated using hydantoin [Spectrus OX103, Spectrus OX1200 , OX1202, OX1240 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, OX1202, OX1240] – 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). "Total residual" is a better indicator of the full germicidal residual generated by these bromo-chloro hydantoin donor products. In most applications, therefore, feed hydantoin donors according to label directions (Table 2) and target total residuals two to three times the free residuals recommended above for chlorine fed continuously or intermittently. Target free residuals as recommended for continuous or intermittent chlorine feed (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 hydantoins. More 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 either case, pH effects can be offset by increasing chlorine residual and/or contact time.

Table 2: Label Guidelines for Solid Halogen Donor Products

All dosages based on application to system volume

Products: Spectrus OX103, OX1200
Type: Bromo, Chloro-Hydantoin. OX103: ~1" tablet; OX1200 (OX107): granular.

Initial Dose	As product 24 to 72 ppm (mg/L)	As total Av. Cl_2 13 to 40 ppm (mg/L)

When system is fouled, repeat initial dose until 1-3 ppm (mg/L) Br2 (i.e. 0.4 - 1.3 ppm [mg/L] as Cl_2) is established for at least 4 hours.

Subsequent Dose	As product 12 to 36 ppm (mg/L)	As total Av. Cl_2 6.5 to 20 ppm (mg/L)

When control is evident, add 12 to 36 ppm (mg/L) as product.
Repeat as needed to maintain 1 to 3 ppm (mg/L) Br2 (i.e. 0.4 to 1.3 ppm [mg/L] as Cl_2) for at least 4 hours.

Products: Spectrus OX1202
Type: DiChloro-Hydantoin in briquette form (~1.5").

Initial Dose	As product 12 to 120 ppm (mg/L)	As total Av. Cl_2 8 to 82 ppm (mg/L)

When system is fouled, repeat initial dose until control is achieved is established for at least 4 hours.

Subsequent Dose	As product 12 to 90 ppm (mg/L)	As total Av. Cl_2 8 to 61 ppm (mg/L)

When control is evident, add 12 to 90 ppm (mg/L) as product every 3 days or as needed for control.

Products: Spectrus OX105
Type:TriChloro-Isocyanurate in puck form (~3") w/small amount NaBr.

Initial Dose	As product 12 to 60 ppm (mg/L)	As total Av. Cl_2 9.5 to 47.5 ppm (mg/L)

When system is fouled, repeat initial dose until total available halogen residual of 0.5 to 10.0 ppm (mg/L) as C_2 is achieved.

Subsequent Dose	As product 2.4 to 12 ppm (mg/L)	As total Av. Cl_2 2.0 to 9.5 ppm (mg/L)

When control is evident, add 2.4 to 12 ppm (mg/L) as product to achieve total available halogen residual of 0.5 to 1.0 ppm (mg/L) as C_2. Repeat periodically, as needed to maintain control.

Products: Spectrus OX101
Type: DiChloro-Isocyanurate in powder form.

Initial Dose	As product 12 to 180 ppm (mg/L)	As total Av. Cl_2 6.6 to 99 pp m(mg/L)

When system is fouled, repeat initial dose until control is achieved.

Subsequent Dose	As product 6 to 120 ppm (mg/L)	As total Av. Cl_2 3.3 to 66 ppm (mg/L)

When control is evident, add 6 to 120 ppm (mg/L) as product daily or as needed for control.

Products: Spectrus OX1240
Type: Bromo, Chloro-Hydantoin in an aqueous dispersion.

Initial Dose	As product 58 to 168 ppm (mg/L)	As total Av. Cl_2 13.6 to 39.5 ppm (mg/L)

When system is fouled, repeat initial dose until 1 to 3 ppm (mg/L) Br_2 (i.e., 0.4 to 1.3 ppm [mg/L] as Cl_2) is established for at least 4 hours.

Subsequent Dose	As product 29 to 84 ppm (mg/L)	As total Av. Cl_2 6.8 to 7.0 ppm (mg/L)

When control is evident, repeat initial dose until 1 to 3 ppm (mg/L) Br_2 (i.e., 0.4 to 1.3 ppm [mg/L] as Cl_2) is established for at least 4 hours.

Products: Spectrus OX093
Type: Solid DBNPA

	As product	As total Av. Cl_2
Initial Dose	12 to 24 ppm (mg/L)	3.5 to 7.0 ppm (mg/L)

When system is fouled, add product to achieve a concentration of 12 to 24 ppm as product (i.e., 3.5 to 7.0 ppm [mg/L] as Cl_2). Maintain until control is achieved.

	As product	As total Av. C_2
Subsequent Dose	7 to 24 ppm (mg/L)	2.0 to 7.0 ppm (mg/L)

When microbial control is evident, add product daily to maintain a concentration of 7 to 24 ppm (mg/L) as product (i.e., 2 to 7 ppm [mg/L] as Cl_2), or as needed to maintain control.

Products: Spectrus NX1102
Type: Liquid 20% DBNPA

	As product	As total Av. Cl_2
Initial Dose	60 to 120 ppm (mg/L)	3.6 to 7.2 ppm (mg/L)

When system is fouled, add product at the rate of 60 to 120 ppm to system volume. Repeat until control is achieved.

	As product	As total Av. Cl_2
Subsequent Dose	36 to 120ppm (mg/L)	2.2 to 7.2 ppm (mg/L)

When control is evident, add product at the rate of 36 to 120 ppm (mg/L) daily to system volume or as needed to maintain control.

- 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. Bromine may enhance biocontrol in 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, OX1240 or OX1200 or by feeding liquid bromide products [Spectrus OX1201 (OX109)] that 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 [0.4 kg per 0.45 kg]) 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 (1.6 kg per 0.45 kg) (generates 100% HOBr) may be required in systems with pH >8.5.
- When feeding bromide products in "demand free systems," 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) and OX1240 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). "Total residual" is a better indicator of the full germicidal residual generated by such bromine donor products. In most applications, therefore, feed bromo-hydantoin donors according to label directions and target total residuals two to three times the free residuals recommended for chlorine gas or bleach fed continuously or intermittently to "neutral pH" systems. Target free residuals for chlorine gas or bleach (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 (mg/L) of chlorine (as Cl_2) for each 1 ppm (mg/L) 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.m combined residuals measured as total residual chlorine) that are five times the recommended free chlorine residual levels.

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, OX1240 or by feeding liquid bromide products (Spectrus OX1201 [OX109]) that 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 [0.8 kg per 0.45 kg]) 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 midrange 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 [0.4 kg to 0.45 kg]) applied to the system or as high as 1:1 (3.6 pounds of Spectrus OX1201 [OX109] per 1 pound of available chlorine [1.6 kg per 0.45 kg).

When feeding bromide products to ammonia-contaminated systems, target total halogen residuals that are two 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 and OX1240 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). "Total residual" is 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 two to three times the free residuals recommended for chlorine fed continuously or intermittently to nonammonia contaminated systems. Target free residuals (using the free residual chlorine test) as recommended above for chlorine fed continuously or intermittently. Target free residuals only if such total residuals fail to provide adequate biocontrol.

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. Some nonoxidizing biocides, when used alone, are particularly ineffective against Legionella, notably quaternary ammonium compounds.

Nonoxidizers are essential supplements to halogen-based programs especially when intermittent halogenation is performed. Nonoxidizers are critical biocontrol components and should be used routinely in systems with one or more of the following properties:

- Open distribution decks
- High efficiency film fill
- Shell-side heat exchangers
- Wastewater makeup
- Frequent process contamination
- Heavy algae biofouling
- General biofouling
- Sulfate reducing bacteria (SRB)

Select nonoxidizing biocides based on performance in toxicant evaluations. Typically, these tests evaluate products against aerobic heterotrophic bacteria. They can be conducted by the GE Microbiological Customer Service Laboratory or performed on-site (see WebAtlas - Cooling/MB Monitoring/ATP Field Test Procedures - Toxicant Evaluation).

Nonoxidizers should be halogen compatible. Most GE biocide active ingredients are halogen compatible. Only methlyene-bis-thiocyanate (found in Spectrus NX1103 and NX104) is known to be degraded by halogens at typical halogen use levels.

Typically, nonoxidizers should be shot-fed to the system volume at 50 to 100 ppm (mg/L). Use molybdate or other measurable salt to accurately determine system volume. Nonoxidizing biocides must carry appropriate EPA-approved end-use label claims, and dosages must comply with label limits. Nonoxidizers will be applied more frequently and at higher dosages in such systems and in intermittently halogenated systems than in systems that are continuously halogenated. A doubling of the system's hydraulic half-life (i.e., time to 75% depletion) can be used to estimate the dosing interval when dealing with an existing biofouling problem. For systems that appear to be under good biological control, reapply nonoxidizing biocides as dictated by the results of biomonitoring.

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

Immediate hyperchlorination is recommended when:

- Total aerobic bacteria counts regularly exceed 100,000 CFU/mL
- Bulk water 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 (mg/L) of a fast-acting nonoxidizing 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 that 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 (mg/L) as Cl_2 for at least six 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 (mg/L) for at least six hours.
7. If bromide is routinely used because of ammonia contamination, increase the bromide feed in proportion to increased chlorine gas or bleach feed. Establish and hold total halogen residuals (measured as Cl_2) of 10 ppm (mg/L) for at least six hours.
8. If bromo-hydantoin products are routinely used, apply according to label directions. An initial dose of approximately 20 to 30 ppm (mg/L) as product may be needed to establish and hold a total halogen residual (measured as Cl_2) of 10 to 15 ppm (mg/L) for at least six 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 (mg/L) of Spectrus DT1402 or 5.0 ppm (mg/L) Spectrus DT1404 for each 1 ppm (mg/L) of total residual halogen (as Cl_2) 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 re-establish 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. Typical conditions for delignification are exposure to 1 ppm (mg/L) free residual chlorine and a pH of at least 9.0. 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. 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. Operate cooling systems that contain such towers at slightly lower pH values or with slightly lower chlorine residuals to help reduce delignification.

Emergency Disinfection

The following emergency disinfection procedure is based on OSHA recommendations. This emergency disinfection should be conducted with the cooling system "off-line." 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. This assumes that a water level controller is in place to avoid sump overflow.
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 program).
7. Add a fast-release, oxidizing biocide (e.g., chlorine gas, liquid chlorine bleach, calcium hypochlorite or chloro-isocyanurates) corresponding to 25 to 50 ppm (mg/L) of free residual chlorine.
8. Add an appropriate biodispersant such as Spectrus BD1500 (BD 151) at 25 to 50 ppm (mg/L) or BD1550 at 35 to 75 ppm (mg/L). An antifoam (FoamTrol AF1440) may be required.
9. Maintain 10 ppm (mg/L) free residual chlorine for 24 hours. Add chlorine as needed to maintain the 10 ppm (mg/L) 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 (mg/L) of Spectrus DT1402 or 5.0 ppm (mg/L) Spectrus DT1404 for each 1 ppm (mg/L) of total residual halogen (as Cl_2) 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 (mg/L) m free chlorine residual. Hold this residual for one 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, reestablish 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 Guidelines) use either a half-mask, full facepiece or disposable respirator equipped with filters capable of removing 1.0 micron particles (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. GE has prepared guidance for its employees regarding self-assessment of their risk of contracting Legionella in the course of their work. Recommendations for personal protection equipment are made in this document. Entitled "Assessing Your Risk of Legionella Exposure," it may be obtained through a GE representative or from GE WebAtlas in the cooling section.

OSHA's Technical Manual Chapter 7 recommends wearing a half-mask respirator equipped with a HEPA or similar type filter, capable of collecting 1-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.

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 "nondetectable" 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

Monitoring for presence of Legionella via culture testing may be performed in certain circumstances. This need may be based upon the exposure of at risk individuals to the system, previous cases or outbreaks associated with the system or the system management's individual safety and health policies. In health care facilities that care for individuals with suppressed immune function, routine monitoring of the outlets of potable water systems should be considered. Additionally, any aerosolizing cooling water systems that may be in the proximity of those individuals should be considered for routine Legionella monitoring. However, it should be noted that the majority of outbreaks in healthcare facilities are associated with the potable water system. GE will help facilitate a culture service if desired. Information concerning this may be obtained from GE Atlas Catalog.

Some limited testing for Legionella may be prudent in order to demonstrate reasonable diligence in addressing the health risk associated with these organisms (i.e. quarterly). In the event of an outbreak, testing for Legionella is required by OSHA (1) to identify the source as well as to document that disinfection procedures were effective. OSHA disinfection protocols require bulk water levels of Legionella to be "non-detectable" immediately after disinfection. During the subsequent six-month required sampling period, Legionella levels should be <10 CFU/mL.

Testing for Legionella in facilities housing high-risk individuals may also be considered. Such facilities would include health care facilities caring for transplant, cancer and HIV-infected patients and facilities housing the elderly. If testing is to be conducted, GE will facilitate culture testing for Legionella with a nationally recognized laboratory. Guidance regarding sampling, shipping and recommended action guidelines is given in the "Legionella Testing Position Statement." This document is available through the GE Atlas Catalog.

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 though 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 nondetectable bulk water Legionella count (e.g., <1 CFU/mL) and a nondetectable 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 may indicate a strong potential for amplification, and the low Legionella count cannot automatically be interpreted to indicate a system with low health risk.

Documentation and Report Generation

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. A good starting point is the utilization of a stepwise approach to determining risk. A "Legionella Risk

Assessment Questionnaire" is available through GE, which will walk interested parties through a facility and help determine if appropriate water treatment, system design, system monitoring, documentation and employee education are in place. 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.

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

Automation of water treatment chemical feed and control utilizing on-line monitoring will greatly simplify and enhance Legionella risk reduction efforts. Incorporation of automated record keeping methodologies via integrated software makes production of reports easy, accurate and fast. Various levels of automation and control exist. Feed of halogens, nonoxidizers and biodispersants may be controlled by a timer, by blowdown metering or by more sophisticated methods such as measurement of oxidation/reduction potential (ORP). Bench chemistry results may be entered into software, which will generate reports and control charts.

A wide variety of feed and control equipment is available from GE. Table 3 outlines these offerings. Please consult with a GE representative to select the appropriate combination of biocide treatments and feed/control equipment for your specific application.

To ensure that adequate information is available to describe efforts undertaken to minimize Legionella risk, records should be kept of instances of mechanical cooling tower cleaning, the frequency and amount of biocide addition, halogen residual levels, results of biomonitoring, and other significant

Table 3

Product	Form	Feed Equipment	Capacity	Type
OX 903	Solid	RediFeed*	Not applicable	Gravity feed, Pressurized feed
BD1550 / BD1500	Liquid	Pump/timer/shot feed	Not applicable	Standard equipment
OX1200	Granular	E2-30-G E5-30-G	30 lb (13.6 kg) 30 lb (13.6 kg)	Kits
OX107		E10-60-G E10-225-G	60 lb (27 kg) 225 lb (102 kg)	
OX103	Granular	Ultra Brom 36	1500 lb (680 kg)	Skids
OX107		Ultra Brom 48	2500 lb (1,134 kg)	
OX1200		I10-225-G	225 (102 kg)	
OX1202		I10 - 225-G-TMR	225 (102 kg)	
Nonoxidizing biocides	Liquid	Pump/timer/shot feed	Not applicable	Standard equipment

of information management products and services to aid in the record keeping and documentation of a cooling tower's operation. These include InfoCalc data management software, and ProCare Alarms and Reports services.

A number of tools are built into the InfoCalc software to enable both manual and automatic data population of the database, as well as numerous manual or automated graphical and tabular report outputs. ProCare Alarms Service provides notification of critical alarm conditions such as high or low pH, sensed by preprogrammed, computerized feed systems at your location. The service is operational 24 hours a day, seven days a week. Reporting capabilities are supplied by ProCare Reports Service, which provides an automated data collection and reporting service available from GE. Information is collected from stored controller data and the reports are processed on a centralized system of servers located at the GE corporate office. The system utilizes GE lnfoCalc as its internal reporting engine. Reports are generated with site-specific data. Output can be in tabular or graphical formats, as well as in specific out-of-compliance parameters. Reports are delivered via e-mail on a daily, weekly or monthly basis

The implementation of a Legionella risk minimization program should be an effort that utilizes such resources as referenced in this document, on-site plant engineering, institutional employee health and safety personnel and the plant water treatment company's representatives. The plan needs to take into account various agencies' recommendations, but also has to be realistic in terms of the actual risks to personnel and resources available to implement the program. Accurate record keeping of these efforts is crucial if an outbreak were to take place. These records will provide the plant with evidence of due diligence in the face of inquiries regarding efforts of Legionella risk minimization.