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COOLING WATER TREATMENT: LESSONS LEARNED

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FACILITIES ENGINEERING
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COOLING WATER TREATMENT: LESSONS LEARNED

1. Purpose. This Public Works Technical Bulletin (PWTB) transmits the document; Cooling Water Treatment: Lessons Learned.

2. Applicability. This PWTB applies to all U.S. Army Public Works activities.

3. Reference. Army Regulation 420-49, Facilities Engineering, Utility Services, April 1997.

4. Discussion. Many installations face problems with cooling systems related to water treatment. The most common problems are the occurrence of scale, corrosion, and biological growth. As a result of these problems, system life, reliability, efficiency, and safety are reduced. Many of these problems are preventable through proper cooling water chemistry treatment. To assist installation personnel responsible for operating cooling systems, a list of lessons learned over the past 15 years has been assembled. The Cooling Water Treatment: Lessons Learned document is attached.

5. Point of contact. Questions and/or comments regarding this subject, which cannot be resolved at the installation level, should be directed to:

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FOR THE DIRECTOR:

FRANK J. SCHMID, P.E.
Chief, Installation Support Policy Branch

COOLING WATER TREATMENT:
LESSONS LEARNED

I. INTRODUCTION

a. Purpose of Report

The purpose of this report is to provide installation managers and plant operators with a ready reference to the main cooling water treatment problem effects and causes encountered in Army installations. The lessons learned provide a general solution that can be of value to each installation in improving their performance.

b. Format and Content

This report addresses major water treatment problems that have been identified at various installations and the lessons learned from the action or lack of corrective action taken. For each major problem area, the trouble effect is defined, the cause identified, and a recommended solution described. This report touches on major problems and is not an all-inclusive Manual.

c. Background

Enormous amounts of water are used daily in cooling water operations. However, water normally contains various levels of contaminants, dissolved solids (minerals) and dissolved gases. Cooling towers and sometimes closed chilled water loops are good environments for promoting microbiological growth. These contaminants and microbiological organisms cause major operational problems and damage to cooling water systems unless they are removed or controlled on a continuing basis. Correct application of chemical treatment programs can eliminate many problems associated with cooling operations. But other problems can and do impact operations.

This report of lessons learned has segregated the problems into two major areas:

(1) MANAGEMENT CONCERNS: Addresses the administration of sound cooling water operations.

(2) OPERATOR PERFORMANCE: Addresses the hands-on execution of a cooling water program.

II. MANAGEMENT CONCERNS

Introduction

Every installation has its own mode of operation and style of management. Cooling water treatment is but one small area of operations but is so critical that complete base operations may cease if procedures are not operated properly.

Observations indicate that major difficulties found in Army treatment systems can be traced to management actions as follows.

LESSONS LEARNED

1. Inadequate Management Support

A serious problem at many Army cooling plants is the apparent lack of attention from management and/or lack of communications between operating and supervisory personnel. This inattention is reflected in numerous ways:

(a) Inaccurate direction or lack of water chemistry knowledge.

(b) Plants operating without assigned first-line supervisors.

(c) Lack of evidence that base Public Works Managers show a physical presence at the plant, or lack face-to-face communications with operating personnel.

(d) Lack of initial or ongoing training for all levels of managers and operators.

(e) Lack of or inadequate safety program.

(f) Lack of proper maintenance procedures, records, and general order and appearance of the plant.

Suggested Actions

With O&M budgets under constant scrutiny, support functions such as cooling plant operations tend to lack a champion unless the assignment of operations is delegated to one specific manager – a manger who should have a good understanding of the operation and has, or takes, the time to monitor operating performance. A training schedule should be established to cover all concerned personnel.

2. Lack of Effective Maintenance Programs

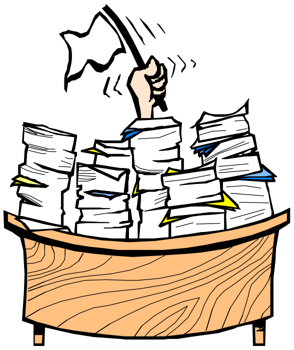
A ready indication of inadequate maintenance programs is the lack of documentation of a planned Preventative Maintenance Plan, poor record keeping, a history of downtime, and/or expensive repair costs.

<u>Suggested Actions</u>

Base management should ensure the assignment of single-point responsibility. Specific duties would include development and maintenance of:

- A Preventative Maintenance Plan.
- Accurate records of tests and repair activities.
- A training schedule for personnel.
- A safety program.
- A schedule for general housekeeping activities to be followed.

3. Inadequate Preparation of Statements of Work for the Acquisition of Cooling Water Treatment Chemicals And/or Support Services



High costs of operation, increased repair costs, cooling system failures, contract disputes, terminations and, on occasion, litigation can many times be traced to the incomplete or inadequate preparation of requests for chemicals/services.

The selection of a good chemical vendor is very important to plant operations. Too often the selection is made on the basis of lowest price per pound of vendor chemicals. What this does is reward the vendor that has the most water in their chemical products! The competitive selection of chemicals and vendor should be based on cost to treat 1,000 gallons of cooling water makeup.

Another factor in buying treatment chemicals is whether to buy chemicals with or without service. Most of the companies recognized as cooling water treatment chemical suppliers do not sell chemicals without service. Also, the quality of service provided varies greatly by company and service representative. Service includes monthly plant visits, technical assistance and possibly other services. Conflicts arise because the company may provide advice that results in unnecessary higher chemical use since the company has an interest in selling more chemicals. Typically, chemical products that include service in the purchase price can cost 5 to 20 times more than the generic chemicals.

Suggested Actions

A standard SOW (Public Works Technical Bulletin (PWTB) 420-49-23, Model Scope of Work for Procurement of Industrial Water Treatment Chemicals) has been developed for the acquisition of water treatment chemicals with/without support services. This model SOW provides details on factors to consider when purchasing chemicals and guidance for preparing purchasing documents. Contact Nelson Labbé at DSN 763-1494, (202) 761-1494 (phone) for help in this area.

4. Lack of Effective Safety Programs

Over 3,000 incidents of employee injuries have occurred over the last three years in cooling and chiller plants. Common safety problems include simply the lack of a formal safety program, not maintaining the program through regularly scheduled safety meetings, not providing back-up for single-shift operators, and lack of safety facilities such as: eye wash basins or shower stalls. Last but not least is the lack of proper ladder and rails, and clear, printed warnings on chemicals used in cooling water treatment.

Suggested Actions

Assign a Safety Coordinator for each facility. Schedule regular safety meetings. Document ANY safety violations. Conduct regular inspections and training in the safe use of chemicals and equipment. Develop a standing list of protective clothing and gear for each work location.

III. OPERATOR PERFORMANCE

Introduction

The successful operation of cooling water treatment programs starts with a good understanding of the goal. The goal is to control deposition, corrosion, and microbiological growth in the system. Microbiological growth not only includes biomass that can foul the system, but pathogenic organisms such as *Legionella* is known to cause Legionnaire's Disease, a pneumonia like illness that accounts for many deaths in the U.S. every year.

The goals can be accomplished through the combined execution of an effective water treatment chemical program coupled with good mechanical maintenance and sound operating procedures. The application of water treatment chemicals alone will not necessarily be effective to achieve the goals. Proper execution of a chemical water treatment program requires accurate routine analysis of the system water conditions. Consistent monitoring allows for the proper corrective action: adjustment of chemical feed, mechanical repairs, and/or operating procedures. The actual control parameters of a chemical water treatment program is site specific, however the means to achieve the parameters remain constant: consistent chemical treatment, proper mechanical maintenance, and sound operating procedures. This would include proper blowdown which is fundamental for success.

The key player is the cooling plant Operator and, of course, assigned Supervisors. A basic knowledge of cooling mechanics and water chemistry is an absolute requirement – whether through formal training or On the Job Training (OJT). Following are examples of operating problems that occur and are often misdiagnosed – with suggested actions for the correct solution.

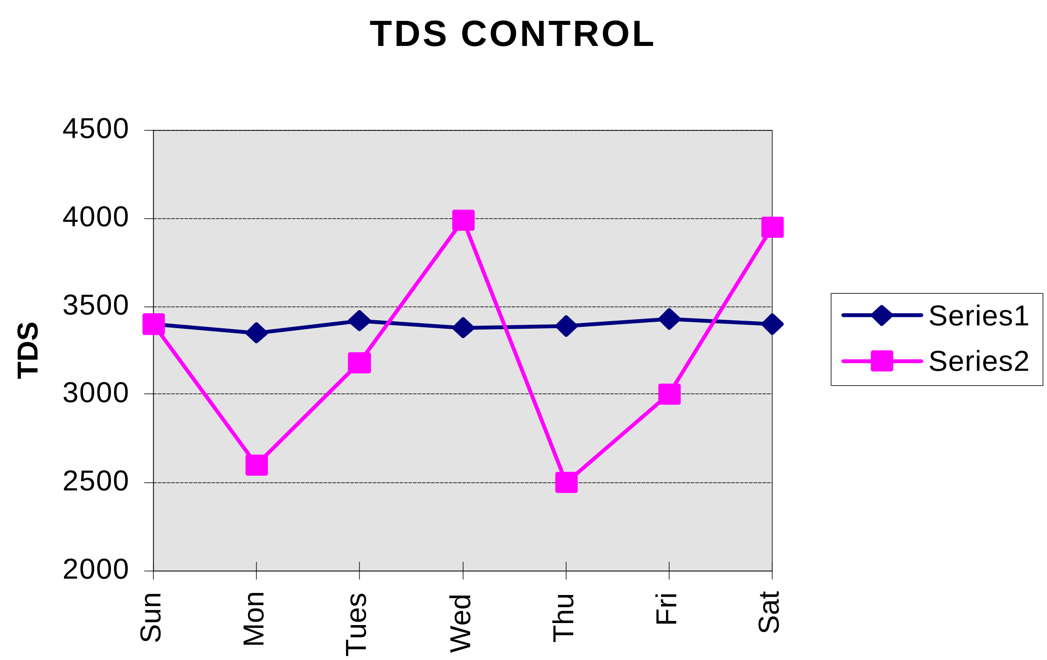
WATER TREATMENT

LESSONS LEARNED

1. Improper Blowdown Is a Major Cause for Scale Formation and Corrosion

Scale and corrosion can result even when chemicals are applied at the desired treatment levels if there is improper blowdown. When blowdown is excessive, scale forming minerals and suspended solids are removed making the water more corrosive. Excessive blowdown also removes the treatment chemicals thereby providing less corrosion protection and also increasing chemical costs. If blowdown is inadequate, scale forming minerals build up in the system to the point that treatment chemicals cannot overcome the tendency to form scale deposits.

In a number of cases, blowdown has been treated as an unrelated procedure to the chemical treatment program, rather than part of an overall treatment plan. Cycles of concentration (COC) determines the water chemistry without chemical treatment. COC is the number of times the constituents in the raw makeup water is concentrated in a cooling tower as water is evaporated. COC is controlled by blowdown and is measured by the amount of *total dissolved solids* (TDS) or *conductivity*. Exceeding the recommended COC for your cooling tower system due to insufficient blowdown can lead to scale even when chemical treatment levels are maintained.



Series 1 depicts continuous or frequent small incremental blowdown.
Series 2 depicts manual, infrequent large incremental blowdown

Control Range: 3,000 - 4,500 ppm TDS for this example. Above 4,500 ppm risks scaling. Below 3,000 ppm is allows for more corrosive conditions and is wasteful of water and chemical treatment.

Suggested Actions

Use automatic blowdown to control TDS wherever practical. This is achieved with an automated microprocessor conductivity blowdown controller. It is better to control blowdown continuously or in small frequent increments rather than infrequent long increments. This avoids wide swings in the TDS level as well as chemical levels.

Small cooling towers frequently employ a constant or regular blowdown to drain. This can be accomplished by throttling a blowdown valve. Another method is to use a timer-solenoid valve combination to achieve regular blowdown. It can also come from a overflow piping in the cooling tower sump. However, these methods are not very efficient with variable load demands. The better method is the conductivity based controller described in the previous paragraph.

Manual blowdown requires too much effort to be effective and is not recommended.

2. Inadequate Control of Microbiological Problems and Suspended Solids

Microbiological growth due to bacteria, fungus, and algae is a problem for Army cooling water systems. Their presence can increase operating costs when biomass insulates heat transfer surfaces. Biomass can also restrict water flow by blocking water passages. Certain bacteria like *legionella* are pathogenic and need to be controlled.

Suspended solids (SS) are things like dirt, silt, and clay. SS are <u>undissolved</u> as opposed to natural contaminants like hardness and alkalinity that are present as dissolved solids. Some SS originate from the system itself when corrosion is not controlled i.e. iron oxide. Heavy accumulation of SS make it more difficult for microbiocides to disinfect a cooling tower or closed chilled loop system much the same as a dirty wound on a person can lead to infection even though a disinfectant is applied. Anaerobic bacteria prefer to exist underneath deposits of SS, scale, and even other bio-mass. Certain bacteria in themselves are corrosive with their by-products causing a *microbiologically influenced corrosion* (MIC). MIC has been known to cause localized tube and pipe failures.

Suggested Actions

Maintain a consistent microbiocide program to maintain general bacterial counts to less than 10,000 colonies/ml. MIC type bacteria like sulfate reducers should be maintained as non-detectable. There are commercially available test kits used for biological monitoring. There should be no visible signs of algae or other biomass in the cooling tower. The microbiocide program can include continuous application of an oxidizing biocide like chlorine or bromine. Another practice is to slug feed a oxidizing or non-oxidizing biocide on a periodic basis. The frequency will depend bacterial levels and the presence of visible biomass.

The dosage of a non-oxidizing biocide is limited by the EPA. It is recommended to apply only the amount of biocide needed. Excessive application is not only expensive, but environmentally objectionable. To get maximum effectiveness from any biocide, maintain good housekeeping practices. Cooling tower systems and closed loop systems should be clean from SS as much as possible. Filtration equipment is useful for this purpose. Another practice is to physically remove SS from low flow areas like cooling tower sumps. Low flow areas in piping systems often require flushing to remove SS. Clean systems are easier to disinfect than dirty ones and will require less microbiocide treatment to control bacteria, fungus, and algae.

3. Cooling Tower Film-fill Is Prone to Fouling

New cooling towers are often specified with the *high efficiency film fill* instead of the splash fill because they provide more cooling with less volume as water passages are tightly packed together. The problem is that they are much more prone to fouling with suspended solids (SS) and bio-mass than the splash fill. SS are things like dirt, silt, and clay. SS are <u>undissolved</u> as opposed to natural contaminants like hardness and alkalinity that are present as dissolved solids. Some SS originate from the system itself when corrosion is not controlled i.e. iron oxide. Clay type SS are especially problematic. Some makeup waters from rivers and streams can contain high clay content. Fouled fill results in a loss of cooling capacity.

<u>Suggested Actions</u>

If possible, specify into the architectural & engineering design, *clog resistant film fill* over the *high efficiency film fill*. The trade off in efficiency is marginal and the maintenance is easier. From an operational perspective, the following is recommended:

4. Maintain good housekeeping practices to remove suspended solids (SS) as much as possible. Filtration equipment is useful for this purpose. Another practice is to physically remove SS from low flow areas like cooling tower sumps. Low flow areas in piping systems often require flushing to remove SS.
5. Maintain a consistent microbiocide program to maintain general bacterial counts to less than 10,000 colonies/ml. MIC type bacteria like sulfate reducers should be maintained as non-detectable. There are commercially available test kits used for biological monitoring. There should be no visible signs of algae or other biomass in the cooling tower. The microbiocide program can include continuous application of an oxidizing biocide like chlorine or bromine. Another practice is to slug feed a oxidizing or non-oxidizing biocide on a periodic basis. The frequency will depend bacterial levels and the presence of visible biomass.
6. Remedial actions to clean fouled fill can include alternate wet and dry exposure coupled with mechanical cleaning.

4. Enhanced Chiller Tubes Are More Difficult to Protect Against Corrosion

Advancement in chiller design has produced the enhanced and super enhanced copper chiller tube. The water side is grooved with rifling which increases the surface area for superior heat exchange. The downside is that this rifling creates small ridges that can entrap suspended solids and lead to tube failures from localized corrosion.

Suggested Actions

Inform your water treatment service company (WTSC) that you have the enhanced copper chiller tubes and that you require extra protection against corrosion of copper. The WTSC should maintain higher levels of copper corrosion inhibitors.

From an operational standpoint, limit accumulation of suspended solids. Maintain a consistent and effective microbiological program to control bacteria, fungus, and algae. Do not let water sit idle in equipment for long periods of time. Idle equipment should have water recirculated regularly - up to 2-3 times per week - to keep suspended solids from settling between the rifled portions of the enhanced tubing.

5. New Galvanized Cooling Towers Are Prone to White Rust

New cooling towers are often specified with galvanized sumps and other structural pieces that are prone to premature corrosion of the galvanizing. This is due to changes in the galvanizing process and the high pH conditions seen with today's cleaning formulations and maintenance water treatment programs. When improperly conditioned, cooling tower sumps less than one year old can resemble a ten year old piece of equipment with impending failure eminent. The result is downtime, repair and/or replacement of the galvanized sump.

Suggested Actions

The process needs to start with the initial cleaning and chemical passivation of the new cooling tower. The water treatment service company needs to be aware of the materials of constructions and needs to provide a cleaning formulation and procedure to the mechanical contractor on the job, that will not promote white rust. High pH (over 8.0) should be avoided during this procedure. The maintenance water treatment program must also be specific for the prevention of white rust. This is achieved either by maintain a pH less than 8.0 or by passivating with high polyphosphate levels for 5-6 days and maintaining a polyphosphate residual of 3-5 ppm as PO_4 thereafter. Obtain an acknowledgment from both the water treatment service company and the mechanical contractor that chemicals and procedures are proper for preventing white rust.

Remedial actions where white rust has already formed require physical removal of the white rust followed by either re-galvanizing metal surfaces or applying special epoxy resins. This requires for the cooling tower to be taken off-line.

6. Lack of Understanding of Chemical Feed Operations Results in Failures

Improper application of chemical treatment can result in failure to control scale, corrosion, and microbiological growth. Many mistakes are due to the lack of understanding of the operation of chemical feed equipment and it's relationship to blowdown.

<u>Suggested Actions</u>

Operators should learn the principles of operation for their chemical control & feed equipment and the fallibilities. These include:

a. *Feed & bleed type* controllers feed inhibitor whenever the bleed circuit is active due to high conductivity. Excessive leaks can cause the bleed circuit never to trip and therefore no chemical feed occurs.

b. Conductivity controllers with *water meter initiated chemical inhibitor feed* are independent of blowdown. However blowdown determines the cycles of concentration and therefore the resulting chemical level.

c. *Cycle-type timer feed* feeds chemical treatment as a function of time and therefore is also independent of blowdown. However blowdown determines the cycles of concentration and therefore the resulting chemical level. Furthermore this type of chemical inhibitor feed requires adjustment relative to cooling load unlike the water meter initiated feed.

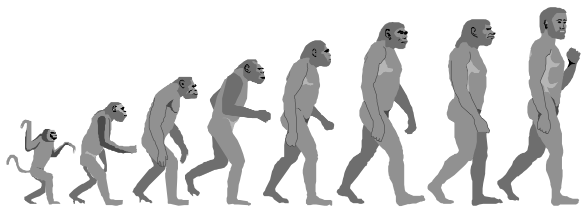
d. *Biocide timers and pumps* are generally used to feed biocides on a weekly / monthly calendar basis. This is comparable to a water sprinkler controller for a garden or lawn. Frequency of dosing is dependent on control of microbiological population. Simply dosing a biocide once or twice a week will not insure microbiological control. Some oxidizing type biocides are fed continuously.

e. Conductivity probes need to be kept clean for accurate readings.

f. Blowdown piping needs to be kept clean.

g. Chemical pumps need to be constantly primed. Tubing needs to be kept in good condition. Cracks in suction tubing can cause pumps to lose prime.

7. Inadequate Sampling and Testing Procedures Result in Improper Chemical Treatment



We have come a long way from the old days!!!

Inaccurate gathering and analysis of water samples can result in losing control of the treatment program. This can lead to a higher cost of chemical treatment, misapplication of treatment, reduced efficiency, and even chiller failure.

Chemical test results are only as accurate as the sample collected. Therefore the sample collected must be truly representative of the system conditions. A poor sample will yield results that call for unwarranted or insufficient adjustments to the program.

<u>Suggested Actions</u>

Specific rules apply to good sampling and test procedures:

Sample Point

Cooling tower water and closed chilled water samples need to be representative of the system. Stagnant piping legs will not give a representative sample of general water chemistry and instead reflect the isolated area.

Sampling Technique

Sample lines should be flushed thoroughly to minimize contaminants from stagnant water in the lines. Sample containers should be clean prior to taking a sample. Containers should be dedicated for sample type i.e. cooling tower, closed chilled water, makeup water, etc . Heavy duty, high temperature, polypropylene, wide mouth bottles are recommended over glass

Tests for trace metals like iron and copper require special preparation. The sample needs to be preserved with acid to bring the pH down to 2.0 or less. This is necessary to prevent the trace amount of metal from being absorbed into the walls of the container.

Interval Between Sample Collection and Analysis

For microbiological testing, it can be critical that the interval between sample collection and analysis be as short as possible. For most mineral testing i.e. dissolved solids, calcium, alkalinity, etc., the time interval is not an issue.

General Laboratory Technique

Laboratory glassware and testing vials should be clean when starting to run tests. Rinse glassware and test equipment thoroughly between different tests and different samples to avoid cross contamination. This is particularly important when measuring conductivity of makeup water samples which are relatively pure compared to cooling tower water samples.

Problematic Testing

The problems that often rise in cooling water testing is the lack of consistency in following correct procedures and /or interpreting results. The following are some examples:

Conductivity and Total Dissolved Solids Testing of Cooling Water Samples

Blowdown is generally controlled as a function of total dissolved solids (TDS) which is calculated from conductivity measurements. Excessive blowdown causes TDS to be too low resulting in waste of energy, water, and chemical treatment. Insufficient blowdown results in excessive TDS and risks the deposition of scale on cooling tubes and carryover of cooling water into the steam.

The key in obtaining an accurate reading is to have a conductivity meter that is properly calibrated for the range that is being tested. One would not want to use a 300 micromhos calibration standard for a reading that is expected to be measured in the thousands micromhos range or visa versa. Some conductivity meters have “built in” calibration, but these must always be verified against an external standard. Comparing one calibration standard against another independently prepared standard, gives some idea if the standards are in agreement and therefore correctly prepared.

Polymer/Phosphonate Testing

Many cooling water treatment programs use all organic / phosphonate programs. Specific test procedures are available to test for these, however it is recommended to send samples to an outside lab for analysis to verify results obtained at the plant.

8. Poor Records Cause Ineffective Cooling Operations

Well documented logs of water testing results are necessary to indicate the current status and trends of chemical treatment and general cooling water operations. Records are particularly valuable for preventing cooling failures or determining the cause of failures that do occur. Well maintained records can predict the condition of the chiller and cooling tower before inspections are performed.

<u>Suggested Actions</u>

Maintain log records that are organized and easy to read or they are not useable. Many operations use computer generated spreadsheets and databases that they create on their own or use from their water treatment service company. Records worth keeping can include:

Makeup Water	water meter readings, hardness, conductivity, silica
Cooling Tower Water	pH, calcium hardness, alkalinity, chloride, silica, polymer, conductivity, inhibitor level, bacterial levels
Closed Chilled Water	pH, conductivity, iron, hardness, inhibitor levels, bacterial levels
Chemical Treatment (general)	dosages, chemical pump settings

Records should be reviewed by supervisory personnel to see if that all parameters are within specified control limits. If they are consistently out of the control range, then corrective action is required.

Test results should be periodically verified by an independent testing laboratory to make sure that accuracy is being achieved.

Army Cooling Water Quality Assurance

The Army has a quality assurance program to provide an independent audit of chemical testing and overall water treatment program effectiveness. Each base can submit water samples to the approved laboratory. For seasonal cooling towers, this should be done at the beginning, middle and toward the end of the cooling seasons. Chemical test results are compared for accuracy and control. The contractor then provides comments and recommendations on how best to improve operations.

9. Inspections Are Invaluable for Cooling Operations

Chiller and cooling tower inspections are necessary to document the effectiveness of the water treatment program. Proper chemical treatment application and record keeping can allow one to predict the condition of the equipment, however the inspection documents the condition. Proper documentation allows for comparison to previous inspections to see if the condition of the equipment has changed for the better or worse. Photos and videos should be used wherever practical.

Please, please, please let it look good! I promise I'll be good from now on.

Suggested Actions

Obtain documents from the previous inspection if applicable, to serve as a reference for the present condition of the equipment.

Inspect the watersides of the chiller and condenser tube bundles. In many cases the view will be limited. Fiber optics video inspection equipment is useful for this purpose. Note the presence or absence of deposits. If present, note the thickness of the deposit and obtain a sample for laboratory analysis. Good control of chemical treatment and blowdown will prevent deposits from forming.

Inspect the watersides for corrosion and microbiological control effectiveness. The metal should not show any pitting due to corrosion attack. The metal should not show any localized dark or green discoloration which is an indicator of corrosion. There should not be any biomass present.

Inspect the sump of the cooling tower. There should be no significant accumulation of dirt/silt/sand or microbiological growth which indicates good control of suspended solids and microbiological concerns.