PAPER NO: TP10-19

CATEGORY: ANALYSIS METHOD

# COOLING TECHNOLOGY INSTITUTE

# A SYSTEMATIC APPROACH TO PERFORMING, DOCUMENTING AND REPORTING INSPECTIONS OF FIELD ERECTED COOLING TOWERS

**CASEY YURKOVITCH**
**GEA POWER COOLING, INC.**

**PHILIP POLL**
**OBR COOLING TOWERS, INC.**



Presented at the 2010 Cooling Technology Institute Annual Conference
Houston, Texas - February 7-11, 2010

## Abstract

A systematic approach is applied to the inspection of field erected cooling towers. Procedures for inspecting structural, mechanical and performance characteristics are investigated with an emphasis on identifying common failures and deficiencies. The distinction between counter-flow and cross-flow cooling tower inspections is examined. In conclusion, a method is outlined for documenting inspection results and the reporting process.

## Introduction

The proper inspection of a field erected cooling tower should be one of the most important maintenance items on an owner/operator schedule. The cumbersome work load associated with performing a detailed inspection contributes to a large quantity of inadequate inspections every year. Although even the best inspection can miss critical issues, the application of a well-organized documentation program provides an effective method for minimizing failure and efficiency losses. A proactive approach to cooling tower maintenance will extend the life of the cooling tower and help limit equipment downtime. Regular inspections coupled with proper preventative maintenance and a minor repair schedule can significantly minimize large capital expenditures on cooling tower equipment. A proactive approach starts with a systematic planning, inspection and reporting process.

In addition to outlining current inspection practices, this paper highlights important yet often overlooked steps such as surveying plant operations, mapping of site conditions, safety and the inspection reporting and recommendation process. Finally, this paper should be used as a general reference only. Cooling towers are engineered structures with mechanical components and should be evaluated as such during the inspection and repair stages. CTI standards should be used for the engineering design of repairs just as they are applied to the design of new structures.

## Off-Site Pre-Inspection Planning

Before the inspection team arrives at the plant site there are several important planning steps that should be followed to ensure full readiness upon arrival. Many owners require outside contractors to obtain specific off-site training and testing. Thorough pre-planning with key customer personnel is essential to ensure that all plant site requirements have been taken into consideration prior to arrival on-site for inspection. It is important to note that this is not intended to be an all inclusive list. Some items that should be investigated are:

- Off-site safety and security training requirements
- Background screening and controlled substance testing
- Required permits and licenses
- Owner safety policies and site-specific safety requirements

Safety in the industrial workplace is paramount. Understanding owner policies and site-specific requirements in addition to OSHA standards is critical. Today, many plants have a zero tolerance safety policy that extends beyond OSHA standards. It is important that the inspection team thoroughly identifies all safety training requirements before arriving onsite. Off-site certifications through a regional safety council or one of the various OSHA training programs is commonly required before contractor personnel will be allowed on site. The pre-inspection schedule must allow sufficient lead time to accommodate all training prior to arrival.

Identify the personal protection equipment (PPE) required at the location. At a minimum safety glasses, hardhat, gloves, steel toe boots and a task specific fall protection harness with 100% tie off should always be used. OSHA requires fall protection for elevated working heights of 6’ or more, but some plants have adopted a 5’ or even a 4’ policy. It is imperative to plan for these requirements before arriving on-site. There may be additional requirements for PPE depending on the site conditions such as hearing protection, goggles, gas monitors, high visibility safety vests, long sleeves and fire retardant clothing. All required equipment should be fully understood, acquired and fit tested prior to arrival on-site to perform the inspection.

Elevated security concerns coupled with strict insurance requirements have caused many organizations to require substance abuse screening and background verification for contractor personnel. Many organizations have adopted standardized certification programs that are processed through government agencies. An example of this is the Transportation Security Administration's Transportation Worker Identification Credential or TWIC™ card for sites at Port locations. Sufficient time is needed to allow for inspection personnel to acquire the necessary identification and certification requirements. Off-site drug testing may be required, so it is important to determine if a specific drug testing agency and location are specified. If not, determine what constitutes an acceptable test for this plant site. If the inspection team has been tested previously, determine whether their tests are valid to meet the plant's test policy.

Depending on the physical location of the cooling towers to be inspected, interstate and even international travel may be required. It is very important that the inspection team verifies the local, state and national regulations and licensing requirements with respect to the work being performed. Almost all of the fifty states require contractors to register their organization before performing any type of work. Some states require individual licenses and permits specifically designated for working on cooling towers.

A significant number of owner companies have a site specific training program that must be completed before the inspection team will be allowed access to the controlled area. This training includes topics such as whether the cooling tower is classified as a confined space and covers the procedures that the plant enforces to access the space. Special permits, a log sheet, entry attendant and pre-entry air quality tests are usually standard with some sites requiring continuous air monitoring. Close attention should be paid to emergency procedures, emergency contact numbers and evacuation routes.

Regardless of the tower size, and even if an attendant is not required, a tower should never be inspected alone for both safety and efficiency reasons. When performing a detailed technical inspection, with safety as a priority, a three man team is recommended as the most efficient way to perform most inspections. Each person will have clearly defined roles and responsibilities. Two will split the physical inspection tasks with the third person taking all of the notes, overseeing equipment and performing the role of entry attendant. This method affords a safe working approach and provides more than one inspector to evaluate observed damages and deficiencies.

## On-Site Pre-Inspection Preparation

The foundation of a good inspection is the initial commencement meeting with the owner's team. Each cooling tower application is unique and has a variety of characteristics that need to be recorded at inspection. It is imperative that the inspection team develop a strong understanding of the client's needs and operational performance characteristics before inspecting the cooling tower. Understanding the operator's concerns with regard to the condition of the cooling tower is the strongest tool the inspection team possesses when documenting the status of the cooling tower. Topics to explore during this initial meeting include:

- Discuss the operating requirements of the tower
- Explore previous repairs and modifications performed
- Uncover both real and perceived issues with the current operation of the unit

The following characteristics are also critical pieces of information for the diagnoses of the problems found during the inspection of the cooling tower:

- Cooling tower manufacturer, model and serial number
- Initial performance specifications and design capacities
- Previous performance tests and results
- Mechanical equipment manufacturer, model and name plate information
- Plan, elevation and overall plot plan drawings
- Water chemistry analyses including the treatment and operating parameters

## On-Site Safety Orientation & Training

During the on-site safety orientation specific hazards near the tower need to be identified. These hazards may include features such as overhead electric wires, water treatment chemicals, process chemicals, plant traffic and any other environmental hazards. After the safety orientation it is time to acquire all permits and perform proper Lock-Out/Tag-Out (LOTO) procedures on any energy sources associated with the operation of the cooling tower. Along with fall protection LOTO is a critical safety procedure that must not be marginalized. After the locks are applied the plant operations personnel should attempt to operate all of the energy sources to verify that the unit is properly locked out. Incidents of injury have been caused by improperly or mislabeled energy sources.

## Performing the Cooling Tower Inspection

### *Record Site Conditions*

Sketch a site map of the cooling tower unit and surroundings with attention to the directional orientation (N, S, E, W). The sketch should be to scale or at least show approximate distances to objects of interest. Obstructions near the cooling tower should be carefully documented as they may impact the performance of the tower and limit the work area. Some typical obstructions include water treatment equipment, tanks or structures. The tower access stairway and safety access ladder should be located on the sketch. Often overlooked characteristics such as riser size, material and location, pump/sump location, basin curb height, electrical supply lines for mechanicals, overhead wires, roads, railroad tracks and material lay-down area should be included as well. Developing a detailed site-map is instrumental in clearly communicating the exact location of problem areas in the resulting inspection report as well as in making clear recommendations for corrective action. An example of an inspection site map is located in Figure one. An example inspection form and a glossary of cooling tower terms are available in Chapter 13 of the CTI Manual and the CTI Website respectively.

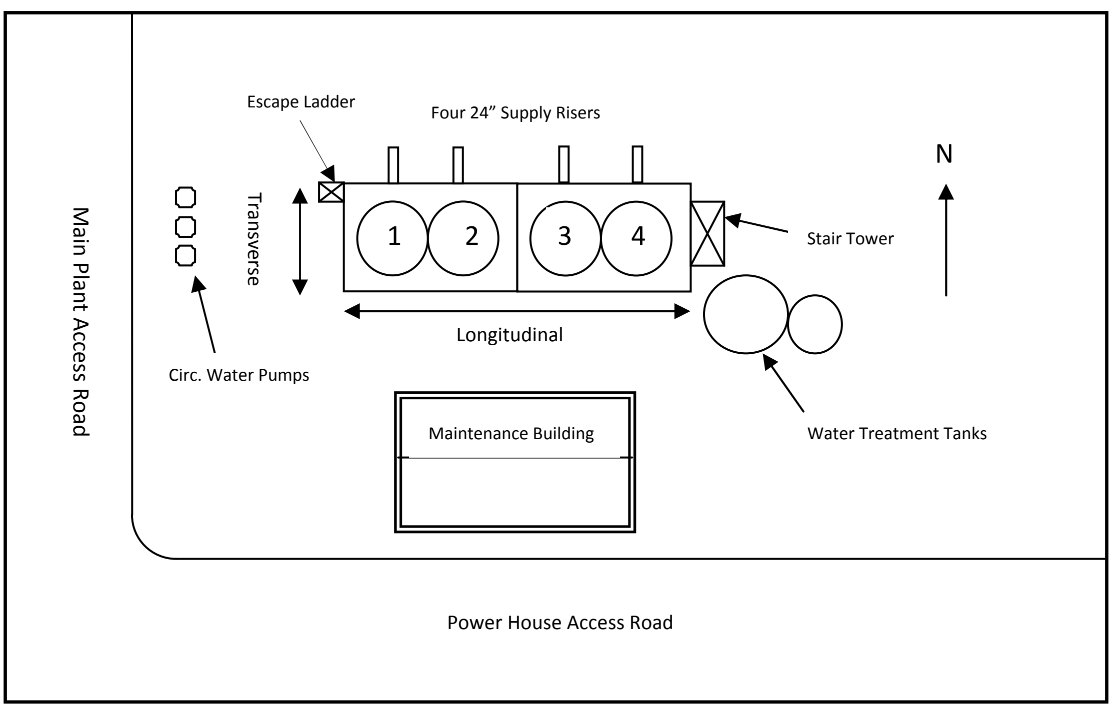


**Figure 1:** Cooling Tower site plan example sketch.

***Initial Perimeter Walk***

The actual tower inspection process begins at the base perimeter of the tower. The first step is an initial walk around the base of the cooling tower structure and auxiliary components. Surveying the site allows the inspection team to develop a plan for the inspection tasks involved and organize the documentation to allow for an efficient inspection process. It is at this time that the tower's structural design should be observed and recorded, with particular attention placed on the types of connections used between structural members and the material of construction used for components.

The initial walk down of the tower provides the perfect opportunity for the inspection team to develop a set of field inspection sketches. The inspection sketches document the overall dimension of the individual fan cells and complete cooling tower structure. The structural bay size should be recorded along with the transverse bent line layout to provide visual support when recording issues found during the inspection process. If engineering drawings are not obtainable during the inspection commencement meeting, the inspection team should produce plan, elevation and plot sketches during the initial site walk down. Examples of structural inspection sketches are located in Figures two, three and four.

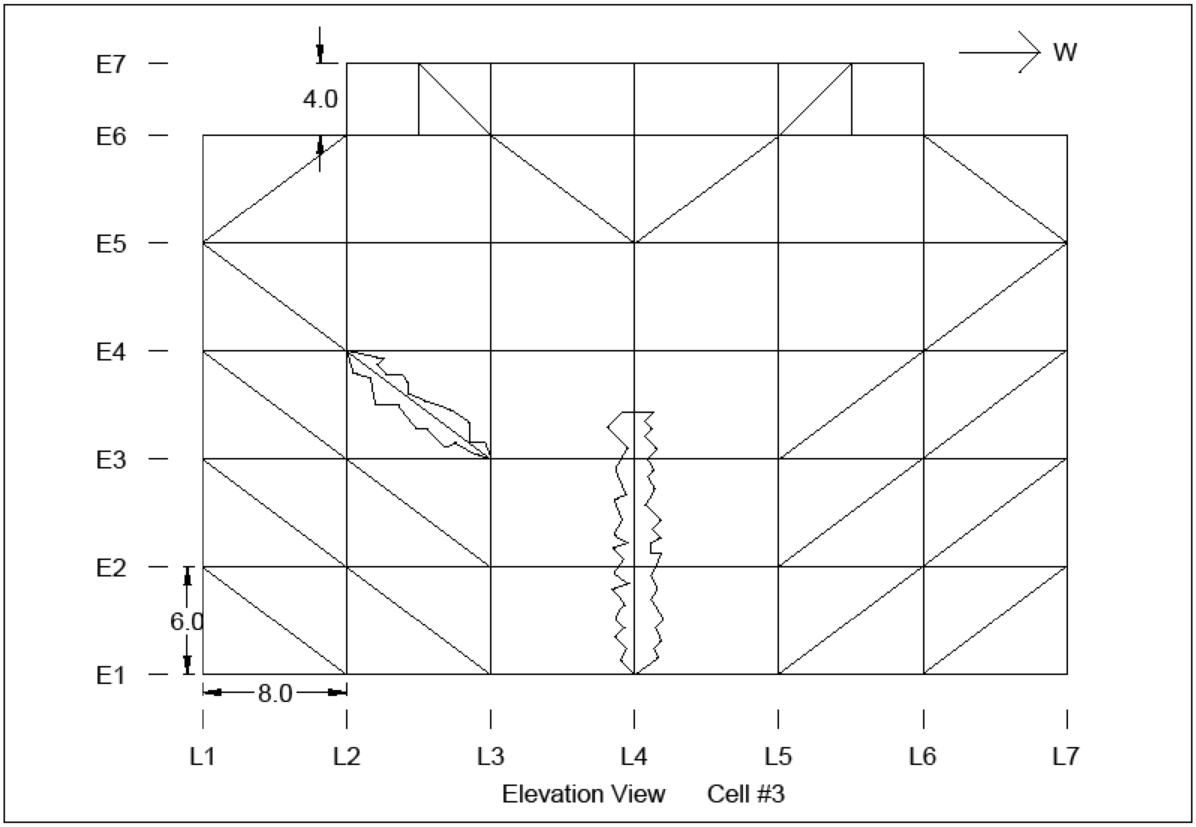


**Figure 2:** Elevation drawing.

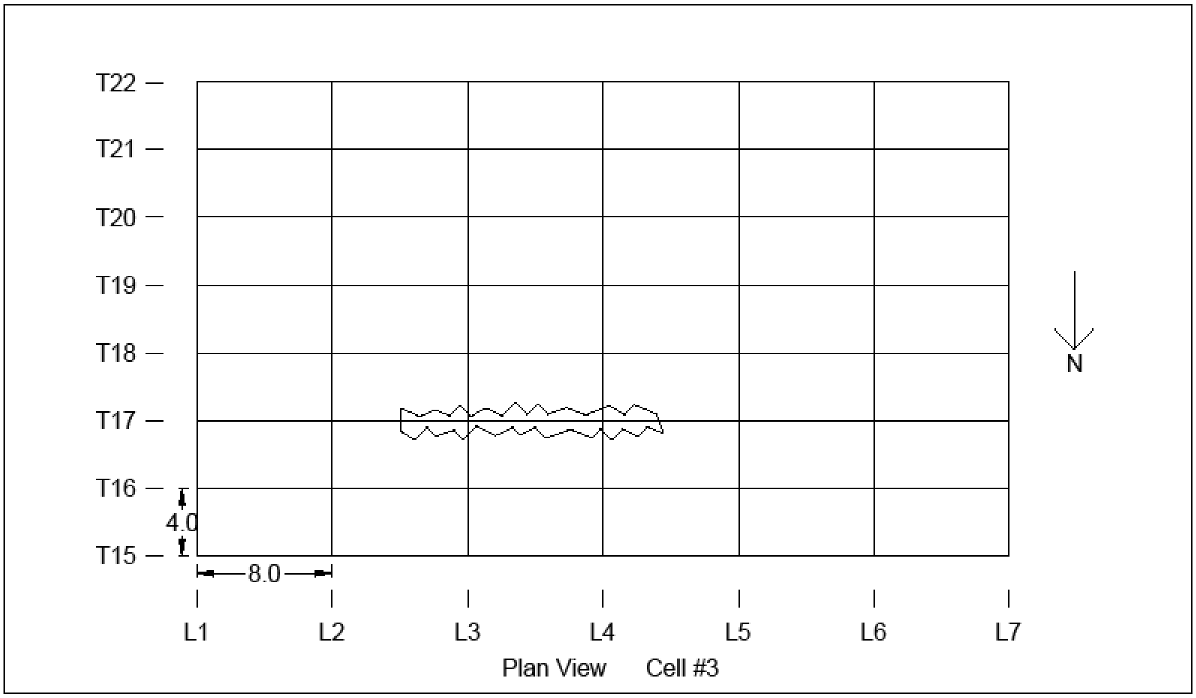


**Figure 3:** Plan view drawing.

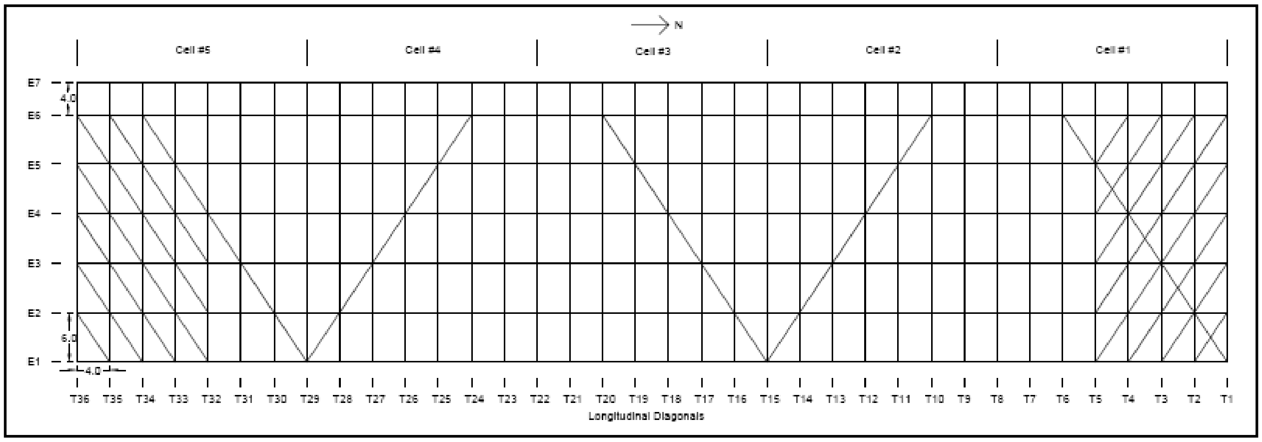


**Figure 4:** Longitudinal diagonal drawing.

Certain applications will allow the cold water basin to be drained during inspection. If available, the cold water basin should be inspected at this time. Inspection of the cold water basin consists of a visual inspection, looking for deficiencies in the basin material and base anchor connections, attention should be placed on cracks in the concrete, leaching of calcium and spalling of masonry material. Careful attention should be placed on recording the material and condition of the sump screens, this also provides the inspection team the opportunity to observe any debris that is passing through the tower. The presence of certain debris may provide indications of specific deficiencies within the tower structure or overall process. A list of common debris and associated issues is located in table one.

| Debris Found | Associated Issue |
|---|---|
| Small wood fragments | Delignification, chemical attack |
| Large wood fragments | Ice damage, mechanical damage, wind damage, wood fill/DE degradation |
| Corrosion products | Pipe degradation, hardware degradation |
| PVC/plastic | Fill/DE degradation, louver damage, distribution damage |
| Bio-film/slime/algae | Excessive biological growth |

**Table 1:** Cold water basin debris and associated issues.

***Exterior Components***

The most often overlooked areas during inspection are the exterior casing, louvers and distribution risers. The casing material, size and weight should be recorded; any leaks or loose pieces should be identified and documented on the inspection sketches. In the case of compressed asbestos board, the material should be checked by a qualified individual to verify that the binder is in favorable condition.

The air intake louvers should be inspected thoroughly looking for signs of deterioration with the louver blades and associated supports. The purpose of the air inlet louvers is to minimize the amount of water lost while it descends through the cooling tower. The louvers should be inspected thoroughly looking for signs of deterioration with the louver blades and associated supports. Because of cyclic wetting and drying at the air intake louvers there is potential for material deterioration. In the case of wood structures, cracks can occur when circulating water evaporates leaving behind minerals which crystallize within the wood. This crystallization results in internal pressure which cause wood fibers to rupture. Although this type of attack is not as devastating as some biological and chemical attacks it is worth noting. In the case of cooling towers that are operated in the winter months, particular attention should be placed on checking for damage caused by falling ice. Common issues found with air inlet louvers are deteriorated louver supports, broken louver arms and cracked or missing louver blades. The perimeter louver posts are commonly found to be affected by wood rot and should be checked to make sure the material has structural integrity.

The condition and size of the distribution risers and valves should be recorded during inspection, this information is valuable to the owner should the inspection find opportunities for an upgrade of the tower components.

| Tower Component | Common Deficiencies |
|---|---|
| Air inlet louvers | Broken/cracked blades, broken support arms, split supports, missing hardware |
| Louver/ perimeter columns | Surface attack, split material, damaged base anchors, missing hardware |
| Casing/siding | Material degradation, leaks, missing hardware |

**Table 2:** Exterior components and associated issues

### *Interior Structure*

A variety of materials have been used over the years to erect cooling tower structures. It is important to note that it is the responsibility of the cooling tower inspection team to record any and every deficiency discovered with the structure during the inspection process. The purpose of the inspection report is to give an accurate account of the structural condition that is found during the inspection. Although recommendations and suggestions can be made it is ultimately the responsibility of the owner to decide how much degradation their structure can endure before taking action to repair.

The outcome of the inspection is directly related to the competency of the individuals performing the work. It is imperative that the inspection team be well versed in identifying issues with the four most common types of structural materials used which are wood, fiberglass reinforced plastic (FRP), concrete and steel. Each material is uniquely different and has advantages in certain applications.

**Wood** – Wood is comprised of several different components namely cellulose, hemicellulose, lignin and extractives. Due to the nature of these components and the environment inside a cooling tower several varieties of wood deficiencies are common. Chemical attack, commonly known as delignification, attacks the surface of the wood and is found in water washed areas. Delignification is the chemical breakdown of lignin within the wood leaving behind the cellulose which is then washed away. Biological attack is present in two forms; surface attack and internal attack. As those names suggest, organisms degrade the surface or internal wood components which comprise a wooden member. As with chemical surface attack, biological surface attack takes place in water washed areas.  Conversely, biological internal attack occurs in areas that are warm and moist but not water washed.

**Fiberglass Reinforced Plastic (FRP)** – In today's marketplace FRP components are prevalent in both the construction of new towers and repairs to existing towers due to their superior decay resistance when compared to wood. It is for this reason that there is a tendency to overlook FRP structure during the inspection process, however, due diligence must be given to the inspection of FRP members. The prevailing FRP deficiency is not caused by the manufacturing process nor by the structural design, it is member cracking localized at connection points caused by over tightened bolts. FRP members must be inspected for cracks and deformations such as bolt hole elongation or general deflection. Ultraviolet radiation degradation or UV damage can range from fading and chalking of the member surface to more advanced instances of fiber blooming which can be described as exposed glass fibers. FRP components such as handrails and stair structures are expected to endure some level of fading and chalking. Refer to the FRP manufacturer as to the severity of degradation and whether the member(s) should be removed from service.

**Concrete** – The mechanisms that cause concrete degradation are numerous, however, the results can be grouped into four key categories; erosion, leaching, spalling and cracking.

- Erosion is damage done to the surface of concrete and is created by chemical attack or by fluid velocity.
- Leaching is a process by which chemicals are removed from the concrete. One of the most notable instances is calcium leaching which typically produces a white powder on the surface of the concrete. Minor amounts of leaching may be beneficial to concrete as it is seen as a process of self healing in areas of minor surface cracks.
- Spalling is the loss of larger volumes of concrete. Many factors can lead to spalling, including improper batch preparation, porosity and corrosion of internal reinforcing steel.
- Cracks are caused by many of the same factors that cause concrete to spall which is why they are typically found in conjunction with spalling. Inspectors must be alert of cracks formed by overstressed members.

Due to the brittleness of concrete, inspectors are not afforded the same visible deformation signs of impending failure as compared with wood, FRP and steel members. Concrete basins and structures should be inspected for these deficiencies, some degradation is tolerable and to be expected. If a question of whether an unacceptable tolerance is reached or a problem is perceived, personnel trained in concrete inspection techniques should be contracted.

**Steel** – Steel is similar to concrete in that there are many causative factors for deficiencies yet the effects are the same; corrosion, cracking and deformation.

- Corrosion is an electrochemical process in that electrons are transferred from one compound to another. This transfer forms two new compounds that are more stable within the environment in which they reside. Steel corrosion is typically thought of as rust, the oxidation of iron in water containing dissolved oxygen. Galvanic corrosion is sometimes found in cooling towers driven by the joining of two dissimilar metals such as the joining of a 304ss pipe flange using galvanized carbon steel bolts. Regardless of the causative factors the net result is a loss of structural integrity of the steel member.

- Cracking and deformation are concerns in areas of high stress such as mechanical supports. Cracking is occasionally found in weld areas at the interface of the weld metal and the steel member due to changes in the microstructure of the steel by the weld heat.

The perimeter of the interior structure should be investigated first, visually inspecting the columns, girts (tie lines) and braces for deficiencies and deteriorated material. Structural areas of concern should be checked with either a hammer or penetration tool to verify that the structural material is of satisfactory condition. Emphasis should be placed on discovering loose or missing hardware, split or broken components and any signs of biological or chemical attack. Digital photos should be taken to document any issues for the inspection report to clearly illustrate the findings.

***Access Stairs and Escape Ladders***

Once the base of the cooling tower and exterior components are inspected, the access points for the fan deck should be examined. The access ladders should be visually checked and, if deemed to be safe, climbed by a member of the inspection team. If unsafe situations are apparent they should be immediately reported to plant personnel and should not be climbed by the inspection team.

Attention should be given to checking the ladder supports, connection points, stringers and rungs. Common issues found while inspecting the escape ladder are loose or missing hardware, broken or damaged stringer/rungs and OSHA violations regarding landings, handrails and safety barricades. Any critical issues found during the inspection should be brought to the immediate attention of plant personnel.

The access stair tower can be checked while climbing to the cooling tower fan deck. The inspection team should be diligent in checking the stairway hardware, tower tie-ins and structural material. Common issues found on stairways are splitting of the vertical stringers, bowing of stair treads and loose or broken handrails. Because of the exposure to exterior elements, wooden stair towers are susceptible to the expansion and contraction of lumber. It is important that the stairway structure is checked and verified to be properly secured. Documentation of the stairways condition should be recorded and included in the final report.

***Fan Deck***

The fan deck of a cooling tower is located above the plenum section of the tower and is the surface that supports the fan exhaust stacks. On most cooling towers the fan deck is used by the operations staff during their daily checks to verify the tower is operating properly. Inspection of the fan deck should start with the recording of the construction material, size and support structure. The fan deck is exposed to a wide variety of environmental extremes. Due to exposure to sunlight, ice and rain that are present on the fan deck over the seasons, deterioration of the deck material is commonly found during inspection. Table three notes the different types of material used for decking and includes common deficiencies typically found during an inspection.

| Material | Common Deficiencies |
|---|---|
| Tongue and groove planking | Biological attack, improper repairs (Air leaks) |
| Plywood | Delamination, biological attack |
| Fiberglass | Foam core deterioration, UV damage |

**Table 3:** Common types of fan deck material and associated issues

The perimeter of the fan deck is commonly enclosed with a safety handrail system. The handrail system should be inspected with the rest of the top deck. Common problems found during inspection are deteriorated handrail posts, missing or loose hardware and damaged toe boards. OSHA guidelines should be consulted to verify that the handrail conforms to industry safety standards.

***Fan Stacks***

When fan stacks are inspected details should be noted regarding the type of stack (straight side, parabolic, velocity recovery, etc.). Document the diameter and height of the stack as well as the materials of construction; metal, wood, fiberglass or concrete. The type and condition of hardware that join the individual sections together and the fan deck hold down hardware must be identified. Care needs to be given in checking for loose hardware and damaged fan stack panels which may be cracked, have soft spots or voids that may be saturated with moisture.

Inspect the shaft guard at the interface of the motor, driveshaft and fan stack. This guard should be tight and not in danger of contacting the drive shaft where it could damage the shaft or cause a fire. Verify that the flashing for the driveshaft cutout in the fan stack is showing no more than a

2" clearance around the drive line assembly. A gap greater than 2" could significantly reduce the performance of the tower by allowing air to bypass the fill.

***Hot Water Basin (Cross-flow Towers)***

Hot water basins on cross-flow cooling towers play a large role in the performance of the unit. The components of the hot water basin are designed to work together to evenly distribute water across the fill. A properly maintained and balanced hot water basin will allow the cooling tower to achieve its maximum cooling potential, assuming that the fill is properly installed and the tower is operating to optimum design specifications.

When inspecting the distribution header note the size of the pipe and materials of construction. The pipe should not show signs of leaks at the joints and should not have any weak or soft spots. Pay careful attention to the condition and frequency of pipe supports. The pipe must be well supported along the entire length of the tower.

Note the size, number per cell and the manufacturer's information on the flow control valves. Mark the initial setting on the flow control valves and check to make sure that they are operating properly. Return the valves to their original position once checked. Signs of leaks, missing or damaged hardware and deteriorated gasket material should all be investigated with respective conditions recorded in the inspection notes.

Distribution boxes should be rigid and capable of evenly distributing the water across the hot water basin. The hot water basin floor material and support joists should be inspected thoroughly and verified to be free of any deterioration or missing hardware. All joints should be located over hot water basin joists and should be sealed. The hot water basin floor should be free of debris and fouling particulates. Nozzles should be free of any obstructions. The manufacturer, serial number, orifice size, bore size and spacing of the nozzles should be recorded in the inspection notes.

The hot water basin curb panels and coupled sealer strips should be solid, securely attached and properly sealed. The fan deck short wall and air seals should be checked for material integrity, adequate connection and sufficient seals. Missing material from the short wall will allow air leakage which will bypass the heat transfer fill media and hinder the tower's performance.

The water level in the basin should be checked during operation. Excess water in the basin can overflow creating two issues. Excess water that is allowed to overflow the inside curb wall into the plenum side of the drift eliminators will result in excessive drift. Conditions where the water is allowed to overflow the curb wall at the louver side can result in damage to the louvers and contribute to the restriction of airflow. Too little water in the hot water basin may affect the distribution spray pattern as the nozzles will not have the appropriate head pressure to function properly. Basin level depth should be maintained at +/- ½" of the optimum operating depth.

The hot water basin handrails and access ladders should be thoroughly inspected and verified to be in acceptable condition, securely attached to the tower and conforming to OSHA requirements.

| Section of Hot Water Basin | Common Deficiencies |
|---|---|
| Support joists | Splitting at post connections, biological attack, sagging, missing hardware |
| Hot water basin deck | Delamination, biological attack, sagging, missing/fouled nozzles |
| Curb walls | Biological attack, leaking seals, missing hardware |
| Flow control valves | Broken frame, missing hardware, obstructions, deteriorated distribution boxes, improper balance |

**Table 4:** Common issues found with hot water basin inspection

***Plenum Area***

The plenum area is the section of the cooling tower that sits directly below the mechanical equipment and follows the fill material with respect to air travel. On a cross-flow cooling tower the plenum section extends down to the cold water basin and is contained by the drift eliminators on both sides. On a counter-flow cooling tower, the plenum section extends down to the drift eliminators and is contained by the exterior casing walls.

***Cross- flow Plenum Area***

The plenum area of a cross-flow cooling tower is one of the most dangerous sections of the cooling tower to inspect. The inspection team should exercise diligence with regard to safety when inspecting the plenum area. Proper fall protection equipment and ladders should be used to aid the team in checking the bay elevations of the tower.

The inspection team should enter the plenum section at the short wall access door directly below the fan deck. If a short wall access point is not available a section of the fan stack should be removed to allow access to the plenum area. After securing fall protection equipment to a proper tie off point and verifying that LOTO protocol has been followed, the team can enter at the fan deck elevation. The inspection team should work their way down the structure checking for deteriorated braces, girts and columns. The location of deficiencies and failed components should be recorded on the inspection sketches and marking paint or flagging material should be used to identify hazardous members for future inspection/repair.

***Counter-flow Plenum Area***

Counter-flow cooling towers are often perceived to have less safety risks than that of cross-flow towers. Due to the difference in plenum arrangement, inspection teams can become careless during the inspection of counter-flow cooling towers. Regardless of the height differences between the two plenum styles, the same safety precautions should be followed to eliminate the risk of injury.

The inspection team should enter the plenum area through the fan deck hatch inspecting the access ladder as they descend. After securing fall protection equipment to a proper tie off point and verifying that LOTO protocol has been followed, the team can work their way across the tie line directly above the drift eliminators. Special attention must be given to make sure that the drift eliminators are not damaged when exploring the plenum area. The inspection team should work their way across the structure, checking for deteriorated braces, girts and columns. The location of deficiencies and failed components should be recorded on the inspection sketches and marking paint or flagging material should be used to identify hazardous members for future inspection or repair.

***Cross- flow/Counter-flow Plenum Area***

The inspection of the plenum area allows for the inspection team to gain access to verify the structural condition of the fan deck. The fan deck joists should be tested for deteriorated members and the connecting hardware for secure unions. All of the connecting hardware for the fan stacks should be visually inspected and the presence of adequate hurricane bolted connections on the fan stack documented. The fan cut radius in the top deck should be observed and a close cut verified. An improperly cut fan radius can create unnecessary turbulence in the fan section and affect the performance of the cooling tower fan assembly.

The partition walls should be inspected for missing sections or air seals to ensure that efficiency is not lost when individual cells are operated independently. In the case of cross-flow cooling towers the transverse partition doors should be checked for proper operation and sealing capability, these doors should remain closed during operation. The drift eliminator section should be inspected thoroughly; the type and installation arrangement should be noted for the inspection report. A section of drift eliminators should be removed and photographed to document the condition and cleanliness of the material, this section should be temporarily left out to allow the inspection team access to the fill section.

***Distribution Area (Counter-flow Towers)***

When descending from the plenum to the distribution area complete the inspection of the ladder stringer and rung material. Before ascending onto the fill section particular attention should be placed on the condition of the fill supports and the viability of the fill section to support live loads. In cooling towers utilizing film fill material caution should be exercised not to damage the fill flutes creating “dead spots” in the media.  Inspect the header and laterals noting the construction materials, sizes and spacing of the laterals. Verify that the header supports are in good condition and that the header and laterals are secured to the tower structure. Confirm that the nozzles are free of any obstructions and note the manufacturer, serial number, orifice size, thread type, thread size and nozzle spacing. Inspect the structure for material integrity. Although this area is typically referred to as the “wetted section”, not all of the structure in this section is water washed so conditions exist to find both internal and surface degradation.

Inspect the fill recording any areas that show signs of damage or deterioration. This is also a good time to verify the fill depth. Where film fill is used, remove several layers of fill at random locations to determine the condition of the fill with regard to fouling, plugging and frailty. The top layer of fill can be deceiving when assessing deposits. It is very common for the top layers of the fill to appear clean while the lower layers have substantial fouling and/or plugging. As water travels through the fill it tends to lose velocity thus causing deposits to form at the lower fill sections.

Be vigilant inspecting places where air may bypass fill such as at the casing interface, partition walls or around structural columns. Air circumvention of fill material has an adverse affect on the efficiency of the unit and tends to exacerbate with operation and degradation of the cooling tower components.

### *Fill Area (Cross-flow Towers)*

Inspect the fill in the lower levels through the louvers noting the type, condition, the depth of the fill, spacing, hangers and hanger supports. Inspect the upper levels of the fill system with the use of scaffolding, ladders, man lift or man basket. Most towers allow adequate room for fill inspection between the fill and drift eliminators as well. This can be easily accomplished by carefully removing one elevation of drift eliminators which must be repositioned when finished. The wetted section structure should be inspected in conjunction with the fill. Serious signs of deterioration and damage may warrant removal of fill for a more detailed inspection.

### *Mechanical Equipment*

Regular preventative maintenance will increase the reliability of the tower, decrease lost operating hours and extend the life of the equipment all adding to the profitability of the plant. A good preventative maintenance plan must include a thorough inspection of the mechanical equipment.

There are a variety of mechanical supports used in cooling towers, the two most common types are ladder and torque tube style supports. The inspection process for all mechanical supports is universal. Mechanical supports should be inspected for corrosion, loose or missing hardware, proper attachment to the tower structure and cracks in the weld joints or the support members.

The motor should be free of major corrosion. Turn the motor shaft to evaluate whether movement is smooth and without the presence of any tight spots or noticeable binding. Vibration switches should be mounted on the mechanical support in an area that accurately reflects the characteristics of the rotating equipment. The wire connection should be inspected and checked for abrasions to the insulation. The switch should be properly adjusted per the manufacturer’s recommendations and should be equipped with a local reset.

Drive shafts should have adequate clearance around the coupling guards, fan stack and the shaft arrestors. Inspect the drive shafts for signs of wear or deterioration. Proper alignment will increase the service life of the drive shaft and flex elements. The gap setting, run out, angular and axial alignment should be checked and referenced against the manufacturer’s specifications. While checking for proper alignment verify that the coupling hardware torque is per the manufacturer’s specifications and that the orientation of the hardware is correct. Flex elements should not be overlooked and special attention placed on verifying the integrity of the element material. Two drive shaft arrestors should be located on the mechanical support, one just inside the fan stack and the other near the gear reducer. They should be robust, free of corrosion and capable of containing a broken drive shaft.

The input and output shaft bearings on the gear reducers should be checked along with the respective seals. Gear reducer oil level should be verified and visual inspection of the oil appearance recorded. In some cases a sample of gear oil should be collected and submitted for analysis. The oil line should be free of leaks and securely attached to the mechanical support. The oil line gearbox interface should consist of a flexible connection to prevent damage caused by vibration. The gear reducer vent line should also be securely attached to the mechanical support and extend through the fan stack so that it is located out of the air stream. It is important that the vent line slopes downward to eliminate the possibility of condensed water collecting in the line.

Fans should be inspected for damage, cracks, wear to the leading and trailing edges. Any weep holes near the tip of each blade should be open to allow for water to drain thus avoiding an imbalance situation. Fan pitch, tracking and tip clearance should be recorded and compared to the design and the manufacturer's specifications. Fan hub and hardware should be free of heavy corrosion and torque verified to be per the manufacturer's specifications.

| Mechanical Component | Common Issues Found |
|---|---|
| Drive shaft | Misalignment, missing hardware, deformed driveshaft, improperly installed hardware, broken flex elements, missing/damaged arrestors, hardware torque, missing set screws, improper key length. |
| Fan assembly | Inconsistent tracking, blade pitch inconsistencies, deteriorated fan blades (leading edge), spacer obstructions in blade clams, missing air seals, hardware torque, blocked weep holes. |
| Gear drive | Leaking input/output seals, input/output bearing wear, excessive backlash, missing/improper vent line, leaking oil line, loose hardware, extreme corrosion, hardware torque. |
| Mechanical support | Cracked/ damaged support material (especially around gearbox mounts), extreme corrosion, broken welds, missing hardware, deteriorated supports, hardware torque. |

**Table 5:** Common issues found with mechanical equipment

## Post-Inspection Report

The objective of the inspection report is to provide a detailed recommended scope of repairs to bring the tower into favorable condition. The report should be produced following standard technical writing guidelines and written to provide sufficient documentation to secure funding for repairs or upgrades.

It is imperative that the inspection report is provided to the owner in a timely manner, is well organized and provides an accurate reflection of the condition of each component of the cooling tower. It is equally important to cite areas where no damage or deterioration is found as it is to cite those areas that do need attention. It is highly recommended that all repairs cited are prioritized based on the potential of safety concerns, damage to the tower and performance degradation.

Sketches that were produced should be inserted as illustrations in the final report.  Detailed sketches displaying the tower structure and location of deficiencies are essential for procuring appropriate services to repair the deficiencies identified.  Photographs taken during the inspection should also be inserted into the report, labeled with the appropriate nomenclature, and any deficiencies highlighted in the description or photo caption.

A diagram of the tower is key to directing the owner's attention to the specific areas relevant to the observations documented in the report.  Examples of tower diagrams and inspection photographs are located in Figures five, six and seven respectively.

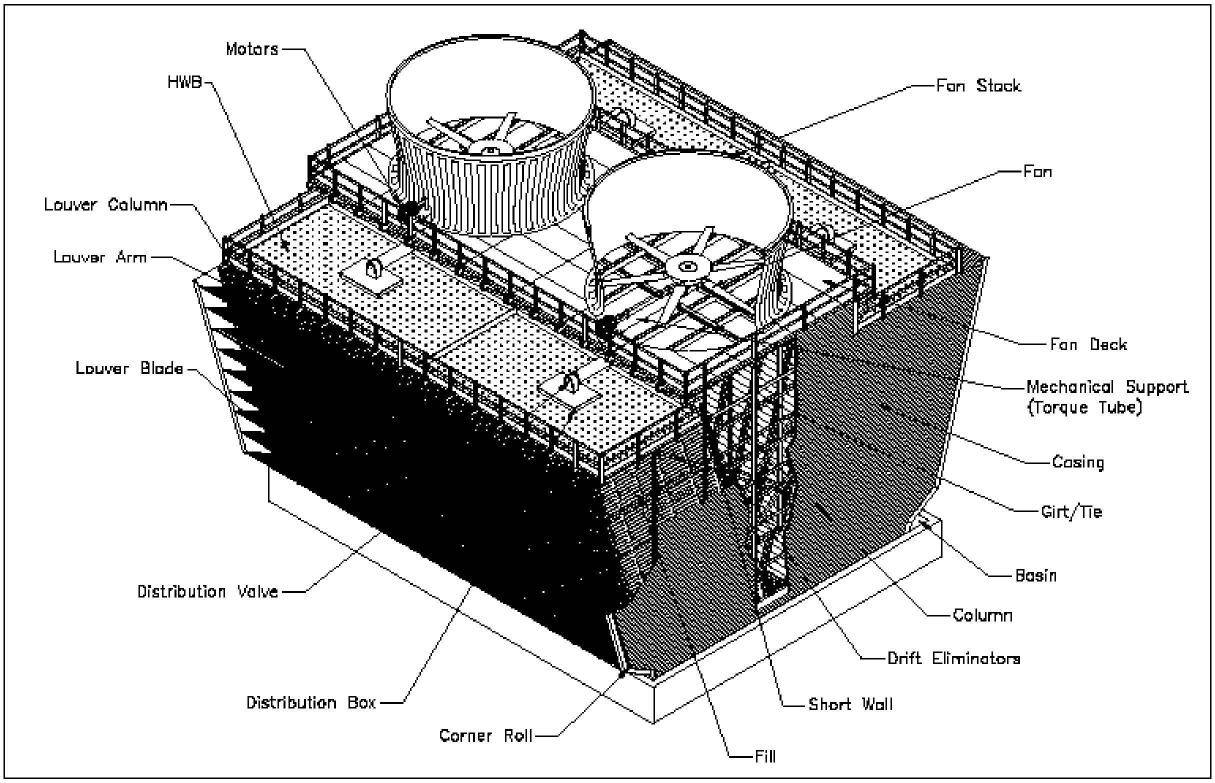


**Figure 5:** Example cross-flow cooling tower schematic

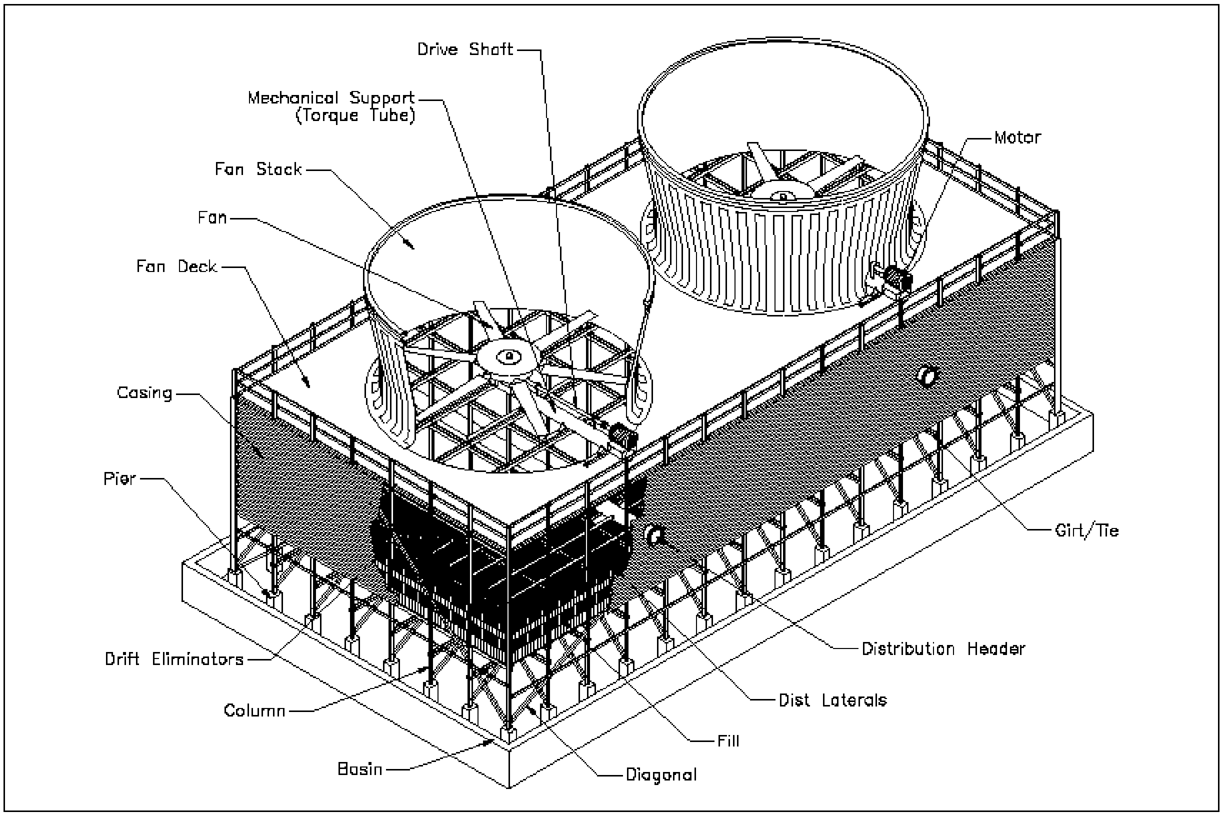


**Figure 6:** Example counter-flow cooling tower schematic

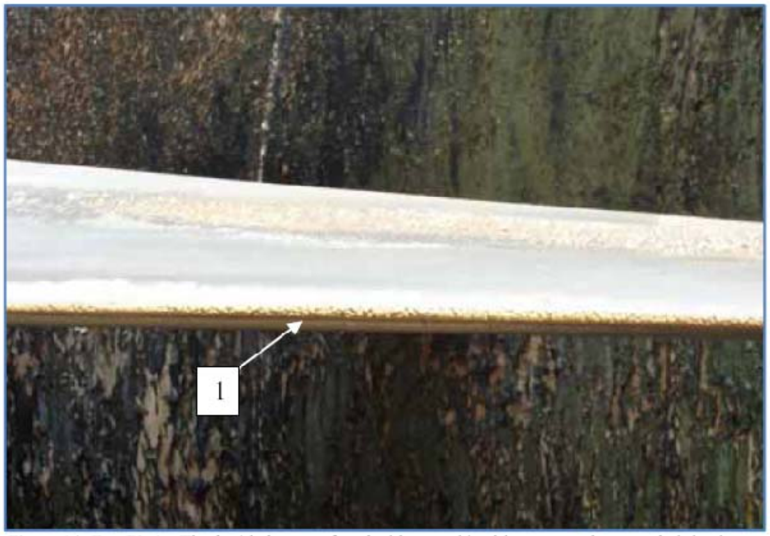


**Figure 14: Fan Blade-** The fan blades were found with a considerable amount of wear and pitting in the fiberglass. Detail point one refers to pitting on the leading edge of the fan blade that is caused by water droplets invading the plenum.

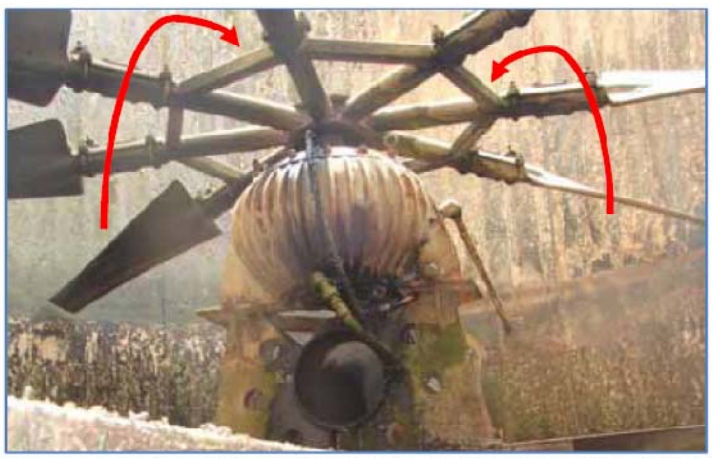

**Figure 15: Fan Assembly-** The fan assembly in the west cell is missing the FRP disk seal. The red arrows display the vacuum that is created at the fan hub causing air to re-circulate the fan assembly.

### *Motors*

The motors on the cooling towers are single speed one hundred and fifty horsepower motors. Each motor is totally enclosed, fan cooled (TEFC) and all look to be in good condition. The motors were not in operation during inspection. Based on the limited availability, both motors appeared to be securely installed and operating properly.

**Figure 7:** Example page of inspection report with inserted pictures and captions

A well managed systematic inspection program will provide the owner all of the pertinent information required to plan, budget and schedule the needed repairs and upgrades necessary to keep their cooling towers at optimal performance.

## Conclusion

A systematic approach to the inspection of cooling towers provides added value to the maintenance schedule of any plant. The implementation of a regular inspection and reporting process provides proper documentation that can be referenced in the case of failure or damage to operating equipment. Consistent monitoring of cooling tower components provides a proactive approach that minimizes large capital expenditures by resisting the “domino effect” associated with material failure. A detailed cooling tower inspection is critical for extending the life of the equipment and decreasing the possibility of costly lost operating hours for critical processes.

## Works Cited


Herro, Harvey M. and Port, Robert D. “The Nalco Guide to Cooling Water System Failure Analyses.” New York, New York: McGraw-Hill, Inc., (1993)

Song, P. and Trulear, M. G. “Identification of Cooling Tower Wood Attack and Methods of Control.” Cooling Tower Institute Annual Conference. TP-86-10 (1986).

Willa, James L. “How to Inspect Industrial Water Cooling Towers.” IWC-89-8 International Water Conference. IWC-89-8 (1989).

Willa, James L. “Iron Rot – The New Nemesis.” Cooling Tower Institute Annual Conference. TP-95-14 (1995).

Moran, Dennis. “Analyzing the Mechanical Equipment in a Cooling Tower for Improved Thermal Performance.” Cooling Technology Institute Annual Conference. Educational Seminar (2009).

Polytech Services, Inc. “Cooling Tower Condition Assessment Description.” (2000).

Puckorius, Paul. “Cooling Tower Wood Decay Identification, Current Incidence and Control Methods.” Cooling Tower Institute Annual Conference. TP-84-10 (1984).

U.S. Army Corps of Engineers. “Engineering and Design – Evaluation and Repair of Concrete Structures.” Chapter 3 “Causes of Distress and Deterioration of Concrete.” EM 1110-2-2002 (1995).

Callister Jr., William D. “Material Science and Engineering an Introduction.” New York, New York: John Wiley & Sons, Inc., (1999).