

HOW TO INSPECT INDUSTRIAL COOLING TOWERS

Cooling towers are an essential piece of equipment for the continued effective utilization of any process that makes waste heat, such as condensing steam in a power plant, or serving heat exchangers in refineries, chemical plants, cooling rollers in steel plants, etc. However, regardless of their importance in the continued efficient operation of any of these processes, they continue to be treated as "step children of industry". I have been dealing with cooling towers for 39 years, and have given a lot of thought to why this neglect is so prevalent on such an important piece of equipment. There are 2 basic reasons, the first being the cooling tower, in most cases, is built of wood. Wood structures, such as homes and barns, do not require as much immediate attention as industrial process equipment. If it were the bearings on the turbine in a 1000 megawatt plant, you may be assured that it would be detected immediately, and something done about it. However, if it is the bearings on a fan motor, or a drive shaft shim pack going bad, this will very seldom be detected, much less repaired in a rush. The cooling tower is a dirty old wood box in the back yard, where you send your water hot, and it's suppose to come back cold. You don't mess with it, and it doesn't mess with you.

The second, and most important, is that in order to learn everything necessary about a tower's condition, it is essential that it be in full operation, which gets the inspector wet and dirty. To inspect a cooling tower out of operation, you may find some of the internal rot, but you will not learn anything about the thermal performance, hot and cold spots, plugged nozzles, uneven distribution basins, excessive vibration, overheating motor and gears, and a myriad of other things that are taking place in an operating tower. If the cooling tower is not in service, less than half the necessary items can be checked.

A third, minor point, is that if cooling towers had escalators, three quarters of the mechanical equipment problems would be prevented. Cooling towers have to be inspected on a regular basis, particularly as regards to mechanical equipment, in order to maintain them in peak operating condition.

Utilities is not a glamorous part of the plant, it is considered a service, rather than production, and almost invariably, the youngest, most inexperienced engineer, supervisor, etc., is given the cooling tower as part of his duties. Just about the time he or she learns anything useful, they are promoted to a "better" position, and another neophyte takes over the responsibility of the cooling towers.

INTERNAL ROT

In 1950-51, the existence of white pocket rot, *porius nigresen*, internal fungus attack, or whatever alias that particular fungi was traveling under, became a major problem with industrial cooling towers. At first it was thought that perhaps an unknown epidemic had struck. But finally the statistics bore out the fact that the increased magnitude of the problem coming about in what appeared to be a rather sudden fashion in the early 50's, was the net result of the industrial cooling tower population being better than doubled during the war years of 1941 through 1945, and all of these towers "coming of age" in the same time period. The majority of internal attack is brought about by this fungus, which has the ability to secrete an enzyme that will hydrolyze cellulose back into its component, monomer glucose, and utilize it for food. This of course, completely destroys the strength of the lumber.

For internal white pocket rot, the best tool for detection, is an awl or heavy duty ice pick. Some people use a hammer or hatchet, but the destruction of good wood with a hatchet is unjustified. With a hammer, it is very difficult to detect deep seated internal fungus attack, without excessive destruction. Drive the pick into the wood at a slight angle. If it does not penetrate further than one fourth to one half inch, (varying with sharpness and diameter of the pick used), you normally will have sound wood. Remember, you will get some penetration in wet redwood, or wet fir. You will get used to the feel as the pick strikes, and as it goes into the wood. If it feels normal, you pull the pick out direct. If it penetrates further than normal, or feels as though you have hit a softened or infected area, bring your pick out with a downward motion, and see how much lumber breaks out. In a healthy piece of wood, the splinter that breaks out will not be more than a fourth to half inch in length, and will show ragged fracture marks. If the lumber is bad, you will get a larger break out in a piece, rather than just splintering wood. In very bad white pocket rot, the pick will completely penetrate the lumber, and the break out will tear a 2"x4" or 2"x6" in half.

ACID DEGRADED

Cellulose is a long chain polymer of glucose, which can be hydrolyzed at extremely low pH's, resulting in another type of attack in a cooling tower, which we term Acid Degraded. Often with the nearby presence of a sulfuric acid unit or a sulfuric acid recovery unit, there is acid mist in the air that will lower the pH to the 1.5 to 2.0 range necessary to hydrolyze cellulose and consequently it washes away as a soluble sugar. This occurs on the outside wood components, such as casings and louvers of towers. In this case, there are needle like crystals left on the surface, which powders in your hand when rubbed. This is the result of the selective removal of cellulose, leaving the lignin. There is a similar type of attack, which is somewhat difficult to discern from Acid Degraded. This is caused by the drying of

circulating water on the outside surfaces of lumber or cement asbestos. The formation of crystals from the dissolved solids as the water evaporates near the surface of the lumber or cement asbestos, causes physical rupturing of the fibers. This is another type of deterioration that takes place on the perimeter areas of the cooling tower. Of course, neither of these types of attack occur inside the cooling tower.

IRON ROT

In today's market, the hardware in a cooling tower, without exception, should be stainless steel. 304 is perfectly acceptable, and is more economical than 316. The 304 or 18-8 series should be used. Brass or silicon bronze hardware is acceptable in most situations, except in applications that may have hydrogen sulphide contaminates in the air or water. However, this material costs more than stainless steel. Therefore, specify and accept stainless steel. Many towers in the past, have been built with galvanized hardware. It is an alarming fact, that currently more money is being spent on repairs occasioned by iron rot, than internal fungus attack, which has been considered the major problem for so many years. This penchant of purchasing agents to save a few dollars by accepting galvanized hardware in a cooling tower, is currently costing millions of dollars in repair work. So, emphasizing the point again, do not, under any circumstances, allow galvanized steel bolts, nuts, washers, in new towers or repair work. Iron rot is an insidious attack that usually goes unnoticed during it's early phase. After the loss of the sacrificial zinc, the unprotected carbon steel starts forming ferric and ferrous oxides in the wood, near the steel. This in turn, promotes a combination of a chemical and biological deterioration condition, referred to as Iron Rot. This type of attack leaves the lumber looking charred or black in appearance. It breaks in a cubical manner, and loses the majority of its strength. Although this type of deterioration does not travel more than one inch to one and a half inch maximum from the source of the iron, this is sufficient to destroy the cooling tower, inasmuch as the joint is lost. The 4"x4" column or diagonal or the 2"x4" and 2"x6" ties may be perfectly sound for 8', but if they have a deteriorated hole around the bolt, one inch in diameter, they are worthless as weight bearing members of the tower. Therefore, they must be replaced, usually in their entirety, regardless of the fact that there is only one inch of deterioration at each end. This past year, a 12 cell, 7 cube, doubleflow crossflow cooling tower, 12 years old, had a "pH excursion" for a period of three days. This tower is in the early stages of iron rot, and the customer has the option of replacing all bolts, nuts, and washers, in this tower now, or replacing a large percentage of the framework lumber in three to four years. If iron rot is detected in its' earliest stages, the hardware can be replaced with stainless steel, and the lumber salvaged. If it has gone a little further, the lumber can be salvaged by redrilling all the holes, and

putting the next larger diameter stainless steel bolt size in place of the corroded bolt. However, after iron rot penetrates a quarter inch around the bolt, the framework is lost. Iron rot is detected by probing with an awl in the immediate vicinity of the steel bolting and castings, looking for softened wood that will crack out in a cubical fashion, and is dark brown to black in color.

SURFACE ATTACK - Delignification (Chemical Attack)

In the early 50's, it was determined that high pH, particularly in conjunction with high chlorine residuals, and possible high sodium bicarbonate levels, was causing delignification or chemical attack. Delignification is the selective removal of lignin out of the wood. The cellulose fibers are the basis of the strength of wood. These fibers have some lignin internal to the cell, but more importantly, lignin gluing the cellulose fibers together. Wood is similar to a brick wall, with lignin being the mortar and cellulose fiber being the bricks. Lignin is slightly soluble in water, and as the pH goes up, becomes more soluble, with a rather sharp increase in solubility around a pH value of 8.5. Chlorine is a non-discriminating type oxidant, and oxidizes lignin as well as other organic matter. The resulting chlorolignin is more soluble in water than lignin itself, and more importantly has a sharp upward break in its solubility curve, about one full pH point lower (7.5) than lignin. Therefore, the combination of high pH and high chlorine residuals, over 1.5 ppm, results in delignification. After the cause and mechanism was thoroughly worked out by the Cooling Tower Institute, US Forest Products Laboratory, California Redwood Association, and other participants, this type of attack just about ceased to exist. This was accomplished by lowering pH to the 7.0 - 7.5 level, chiefly by the addition of Sulfuric Acid, and by lowering chlorine residuals to 1.0 - 1.5 ppm. In recent years, this problem has resurfaced, due to the necessary increase in pH, brought on by the elimination of chromate treatment. However, most of the smaller wooden members, such as fill and drift eliminator slats, are now being made of plastic, which reduces the economic impact of chemical attack. Plywood is particularly susceptible to delignification.

BIOLOGICAL SURFACE

Also in the early 50's, there was a prevalence of what was termed biological surface attack, which is a fungal (ascomycetes family) attack, that takes place in the flooded area of the cooling tower, on the surface of the lumber. Surface attack can be detected by scraping across the surface of the lumber, with either an ice pick or your fingernails, and determining if you come up with cellulose fibers stuck under your nails or on the tip of the ice pick, or whether the material is soft and crumbly. This will immediately determine whether you are into a delignifying situation, or whether you have biological surface attack, or some type of surface deposits. Color is a good

indication with delignification appearing light or white in color, and biological surface attack usually appearing brown. However, color can also be deceiving where there may be a light colored phosphate or calcium carbonate scale, which is white in appearance, without delignification being involved. A coating of light colored mud or phosphate on the surface of fill slats may obscure the fact that there is biological surface attack. Therefore, examining the scrapings from the surface of the lumber is necessary to determine which of these two types of attack may be present. When delignification was brought under control (early 50's), it was determined that the addition of chromate in the circulating water would effectively control biological surface attack and would help to forestall internal fungus attack. It is interesting to note, that although there is considerable action on the part of regulatory agencies to eliminate chromate from cooling tower systems, there are still many plants continuing the use of chromate. The question is whether chromate in the effluent, or chromate in the cooling tower is prohibited. The elimination of chromate from cooling tower water treating, is a serious blow to cooling tower longevity. Those towers, that have for many years been adequately protected against most types of attack by the utilization of chromate in the circulating water, are now being subjected to biological surface attack, internal white pocket rot, and most particularly to iron rot, where they have been taken off chromate and put on a non-chromate treatment regimen. Therefore, even with the difficulties involved, remember, as regards to the life of your cooling tower, stay with chromate as long as you possibly can.

PERIMETER

Determine riser size, material, location, and condition. Circle the tower very carefully, determining the location of all auxiliary equipment, its function, and condition. This includes determining what chemicals are being added where, by what mechanism, and by what control parameters. For instance, the addition of sulfuric acid for pH control, should be checked to see that it is not being allowed to run directly from an acid line into the basin, where it will destroy the cement in the curb, or sink straight to the bottom and deteriorate the adjacent floor area of the basin. Instead, it should be put into the tower by mixing it with a flow of circulating water in a wooden trough, or a lead lined wooden through with baffles, which accomplish mixing prior to flowing into the basin. Likewise, chlorine should be mixed and added properly to the cooling tower to avoid loss of chemical. Chemicals should be added on a continuous, or at least regular schedule. The location of the makeup line and its functioning, whether on level control, automatic valve, or manual control, should be noted. The location of the makeup line and its functioning, whether on level control, automatic valve, or manual control, should be noted. The location of the blowdown and the path of its disposal, should

be determined, so that appropriate recommendations can be made concerning possible EPA problems with the cooling tower discharge. Other lines flowing into or out of the basin, must be carefully located and described. Quite often you will find a steam condensate exhaust line from steam driven pumps, being dumped into the cold water basin. This summer, there were two instances of 6" sidestream filter line being put into the cold water basin. In a ten cell, six cube, doubleflow crossflow, a stream of water is being taken off the hot water header and run thru an elaborate sidestream filter setup, which of course is good. However, the effluent from the sidestream filter is then piped back to the cold water basin. The thermal performance test on this unit revealed the fact that a 0.7°F rise in the cold water temperature in this 107,000 GPM cooling tower, was due to this bypassing of hot water directly into the basin. This same company, had just paid approximately \$250,000.00 to better the cold water temperature by 0.9°F, in a four cell crossflow tower to improve their production efficiency. Whereas in a ten cell tower, 0.7°F is being given away, strictly for the lack of a 6" line being run to the top of the tower and dumped into the distribution basin, rather than in the cold water basin. Even the addition of a small pump, if necessary to accomplish this, would be a minor expenditure, compared to the differential in cooling tower performance. The basin should be checked for height above grade, cracks, spalling of the curb brought about by icing, acid, etc.

CROSSFLOW

There are more crossflows in existence than counterflows. A crossflow tower has louvers all the way up the longitudinal sides of the tower. It draws air in a horizontal direction across the water, thru the drift eliminators, into the plenum and out the fan, while the water falls down in a slight angle off vertical. A counterflow tower draws air thru the bottom air inlet louvers in a vertical direction, counter to the falling water.

In order to make a complete inspection, several dimensions need to be recorded, to be utilized in subsequent calculations, to determine whether or not there is any mechanism by which the tower's thermal performance can be increased. Therefore, the first thing is to count the number of bays long and multiple it by either the 4' or 6' involved, and the same on the width (6' or 8'). The height can be measured by counting the rungs of the ladder at one end, which are invariably one foot apart, or by measuring stair treads and counting the stairs as one ascends the tower.

LOUVERS

Determine the height, vertical spacing, size, and condition, of the air inlet louvers. Determine the material of construction, which is 3/8" cement asbestos board, 8 oz., 4.2 corrugated glass reinforced polyester plastic, or on a few towers in the north,

plywood. Determine if there is delamination of CAB or plywood, and any surface deterioration. Look for scale accumulation, algae, and mud. Check the hardware for type, such as brass, galvanized steel, stainless steel, and condition. Check the 2"x4" lookouts, that support the louvers, for chemical attack, and scale formation. These deposits can increase until the weight will overload the louver and break it, or they can become an obstruction to air flow. One tower, recently inspected, had silica scale obstructing one third of the total air inlet area, even though the vertical distance between louvers was 36". Cement asbestos louvers have a tendency, particularly under heavy ice load, to crack. Sometimes the pin on the bottom end of the plastic support rod is lost. The missing louvers can be seen rapidly, and the broken ones spotted by leaks coming through the cracks. Broken support rods, and deteriorated hardware, which is loosening them, can be detected by slight sags in the horizontal line of the leading edge of the louvers. At this time, also look to see if there is water splashing over or out of the louvers anywhere. Quite often, pluggage in the distribution deck will cause water to overflow onto the top louver and splash out, which in northern latitudes causes appreciable ice damage during the winter. Also, the corner rolls at the end of the tower, are often delaminated or broken at the lower corners, or in the bottom angle section, that conducts the water back into the basin. This results in leakage onto the ground, and consequent corrosion of adjacent equipment, forming of puddles, algae, mud, and ice. On wood louvers, we look for delignification, mud, scale, acid degraded, or rupture from drying salts. Louver posts are checked for mud, algae, scale, and surface attacks.

CASING

The casing of a crossflow tower is the two end walls. In the past, these walls were built of double redwood construction. However, it was found that this led to abnormal amounts of internal fungus attack in the dead space between the two walls, and during the early 60's, this type of construction became obsolete. However, there are some of these towers still in operation, and they must be checked thoroughly for this type of attack on the inside casing. The typical crossflow has either 3/8" cement asbestos board, or 8 oz., 4.2 corrugated glass reinforced polyester plastic casing. These are checked for broken areas, and deterioration from leaks making scale and rupturing the CAB. Leaks also cause algae growth. Check for corrosion on the fasteners. The preferable fastener for CAB is a stainless steel lag screw, with a stainless steel washer with neoprene bonded to the underside of the washer. For fiberglass, it should be a stainless steel ringshank nail, with the same type of stainless steel bonded neoprene washer. There are very seldom any major problems or repairs that are necessary on these CAB or GRP outside casing walls, on crossflow towers. The major concern is broken corner rolls allowing leaking at the bottom corners. However, occasionally towers are found where the cement asbestos

board is delaminating or softening. The softening is usually brought about by acid mist in the area or by extremely high total dissolved solids, which are precipitating internally, and rupturing the structure of the cement asbestos board. Also, occasionally cement asbestos board is lost due to poor original manufacture. Of course, current EPA regulations prevent any further use of this material, and it is slowly being replaced on existing towers with GRP. All new construction is GRP. When cement asbestos board is replaced, you must contact your local EPA office and have them determine whether or not they are going to classify this material as friable. That will determine by what means and in what class dump it must be disposed, in order to properly meet the regulations in your area. The reason for emphasizing area, is that as a practical fact, different EPA offices take a different view on handling this material.

FILL

Determining the type of fill, and its vertical and horizontal spacing. Check the condition, through the louvers, of the lower two cubes (6' vertical increments) of fill. With wood fill, look for delignification, or biological surface attack. Look for any type of scale or contaminant deposits on fill. Check to see that the fill is all in position. Look for ice damage on the outside portions. With plastic fill, check to be sure that it has been clipped to the hanger, so that it does not rattle out of position, and fall out. Polyvinylchloride coated steel wire hangers should be checked for peeling of the PVC, any corrosion that appears to be taking place in the wire, and breakage or knocking down of the hangers, due to ice or other loading conditions. With GRP hangers, look for breakage of the hanger, and deterioration of the half round wood supports that go thru the tops of the hanger to hold it in position. It is interesting to note, that many towers with plastic fill hung in fiberglass hangers, are still dependent on a half round wood slat at the top of the hanger, for support. This means delignification is still a hazard in this type of tower.

Now go inside the tower, thru the access door in the end wall, and onto the center walkway. Enter the basin itself from this walkway, checking the bottom of the basin for mud, debris, or any other contaminants. Ascertain the amount of foam or debris floating on the surface of the basin. Then duck under water, beneath the bottom drift eliminators, and come up between the back side of the drift eliminators and the fill. You are then able to crawl up at least one or two 6' levels, to determine the condition of the inside fill and fill hangers. When checking the fill from the outside, you are only able to see in effectively three or four feet, because you are looking from light into dark, thru falling water. However, from behind the drift eliminators, you are looking towards the outside louvers, and from dark to light. From this vantage point, you can see all the way thru the fill and determine that all slats and hangers are in position,

with no sagging or breakage. From this vantage point, also check the transverse 2"x4" ties that penetrate the drift eliminators, to determine if any internal fungus attack has penetrated thru the drift eliminator area. Once these ties reach the flooded area (within 2' of the back side of the drift eliminators), there will be no more internal rot, because it does not exist under flooded conditions. Also, while in the basin, if the water level is sufficiently low beneath the bottom fill (8" to 9"), then one can check for hot and cold spots under the fill. This will indicate any distribution problems and possible performance increase availability.

When the hot water leaves the nozzles in the top of the tower, within a very few feet, approximately one third of the heat is transferred to the air, because of the large driving force (enthalpy) between the water and air streams. The next one third of the heat load is transferred by approximately halfway down thru the tower. The last one half of the tower is transferring less than one third of the total heat load, due to the continuing decrease in driving force. The cold water temperature is asymptotically approaching the wet bulb temperature. Low approach towers are more expensive because the water must be held in contact longer in order to decrease this difference between wet bulb and cold water temperatures. The net result of this effect is that the water is being cooled thru the tower in a logarithmic manner. When it reaches the basin, and mixes with other water of different temperature, this mixing is an arithmetic mixing. Therefore, cooling is lost because the water was cooled logarithmically, and is mixing back together arithmetically. An area or a cell making hotter water can destroy the effect of the last two or three degrees, that were so hard won by the cell making colder water. This is most important, because it is the largest single and most common factor in the loss of thermal performance industrial cooling towers today. Having different flow rates in various areas or cells of the tower, results in an overall decrease in thermal capacity. The original detection of this problem, can be made while in the basin. The water near the louvers will, of course, be somewhat colder than that near the drift eliminators, because of having the fresh air. Therefore, there will be a gradient in temperature from louvers to drift eliminators. However, there should be no appreciable gradient in temperature in the longitudinal direction thru the tower. Survey temperatures longitudinally thru the tower with palms up, to detect any significant difference in temperature. Hands are not sensitive enough to give accurate, absolute temperatures, but they can indicate differences rather closely. Therefore, outreached hands, palms up, can readily detect differences in temperature.

Determine the condition of the hardware and the framework in the wetted area. Normally this framework will be in good condition, with a minor amount of chemical attack. Iron rot can affect this

area. Also, while behind the drift eliminators, check the transverse partition walls in the flooded area. These can be CAB, wood, or fiberglass. The cement asbestos and fiberglass generally exhibit no deterioration in this area. The wood will sometimes have delignification or biological surface attack.

STAIRS - LADDERS - HANDRAILS

Come back under the drift eliminators and out of the basin. Go up the stairs to the top of the tower, checking the condition of the hardware, treads, and stability. Usually there will be no internal rot on the stairway, because it is too dry. Likewise, there will be no significant surface attack until the stairway is quite old. The normal problems consist of split treads, corroded steel bolts causing splitting of handrails, kneerails, and framework members. Sometimes the long straight stairways on older towers will be somewhat loose and need to be reattached with additional braces to the side of the tower. In newer towers, OSHA requires a landing every eight to ten vertical feet, and this type stairway is much more stable. Coverings on the stair treads and landing must be checked. Quite often, antislip material, such as expanded stainless steel, aluminum, or a grit painted on or glued onto plastic, is utilized. When expanded steel is used, it often is rusty and should be removed to avoid a tripping safety hazard. Sometimes the sheets of plastic with imbedded grit are loose on the landings or treads, and must be renailed. Stairways with galvanized hardware, should be refitted with stainless steel, prior to splitting from corrosion products.

All towers are required to have two methods of escape. If a ladder is used, it is check for deterioration, particularly the rungs. Normally the rungs are made of oak, inasmuch as redwood does not have sufficient structural strength to serve as a rung. However, this oak should be pressure pretreated, because of its tendency to rot out quicker than redwood. An aluminum ladder is better and should be used for replacement. The connecting hardware to the side of the tower, should be examined carefully for corrosion, and soundness. All access ladders on cooling towers, should have cages (back scratchers). These are normally hot dipped galvanized steel, which is satisfactory in this service. However, the better material is again aluminum. The top of the ladder at the fan deck should have a bar or swing gate, that blocks the ladder until needed. On top of the tower, check the handrails, kneerails, and their support posts. They should be all intact and tight. The handrail and kneerail should both be bolted, if not, at least the handrail should be bolted, not nailed. On a crossflow tower, this handrail always extends around the top fan deck. However, to encourage proper maintenance of the distribution system, there should also be handrails and kneerails extended around the outside of the distribution deck. Check any davit, pulley, or other apparatus for taking materials on and off the top of the tower. Quite often, these davits are mounted in such a manner that they begin

to depress the fan deck floor, for lack of any framework under one or more of their legs. This results in a dangerous situation, when trying to raise or lower heavy loads. The condition of the davit, hardware, corrosion, etc., is to be checked.

FAN STACKS

When on top of the tower, don't try to check out everything about one cell first, such as, fan stack, motors, gears, etc. Even with notes, some items will become confused and some overlooked, that should be noticed, as compared to concentrating on one or two items at a time. This means several trips back and forth across the top of the fan deck. Now check out the fan stacks. There are still old stacks in use of redwood construction, sometimes with aluminum or galvanized steel, lower venturi sections. On these stacks, look for deterioration in the lumber itself, and check for corrosion in the lower steel or aluminum venturi throats. The majority of all stacks today, and all new stacks being installed, are fiberglass reinforced polyester plastic. Measure the diameter and height of the stack, and diameter of the hole in the fan deck. Check for excessive vibration, by watching the top, and by placing your hand on each stack panel. Look for any cracks or breaks in the stacks. Look for any place that the fan has struck and damaged the stack. Check each vertical joint where the sections are put together with bolts. These bolts should all be stainless steel, if not, they should be changed to stainless steel. They should have a lock tight type nut, to prevent loosening, due to vibration. This is a common omission on many stacks, and causes the loss of nuts and bolts. Determine the number of bolts and nuts that are missing or loose. They must be kept tight, in order to maintain the structural integrity of the stack. It is common in velocity recovery stacks, to have loose bolts in the upper flanges, which contributes to excessive vibration in the stack. Missing bolts in stack access doors is the rule rather than the exception. Mechanics habitually put back only three or four bolts, rather than the normal ten or fifteen, when they remove this access door, to make it easier to get in and out the next time. However, the net effect of this procedure, is to destroy the integrity of the lower portion of the stack. This area is most important, because this is where the fan blades are located. This leaves the access door loose to the point, that in many instances, it is leaning in far enough to start tipping against the end of the fan blades. There is normally one or two inches of tip clearance to maintain maximum fan efficiency. Therefore, if this door leans in only one and a half inches, there is danger of a fan wreck. This can cost many thousands of dollars for a fan, a drive shaft, the fan stack, possibly a gear box, and if personnel happen to be in the area, possibly the loss or injury of a man. This is a very common fault that is found in over half the towers inspected. Therefore, special attention must be paid to these access doors.

The drive shaft should go thru a hole in the stack only 2" to 4" larger in diameter, than the shaft itself. However, many times the hole is cut several inches larger than the shaft, and even worse, quite often, a slot is cut from the fan deck up to the top of the shaft, so that the stack may be set down over the shaft without its removal. This again cuts into the structural integrity of the bottom ring, by having cut out the bottom flange. Any hole near the upper portion of the tower, that allows air leakage, is a source of performance loss. The static pressure thru a crossflow tower will be 0.4" to 0.5" of water, to force the air thru air inlet louvers, falling water, fill, drift eliminators, plenum, and out the top. However, a hole in the bottom portion of the fan stack, or anywhere near the top of the tower, will have practically zero pressure drop between it and the fan. Therefore, air will preferably enter thru this hole area, rather than coming thru all the tower. A relatively small hole may bypass 5% of the total air, thus effecting thermal performance. In wood stacks, check the bands or rods around the stack for tightness, and corrosion. Some fiberglass velocity recovery stacks were designed with "spider" cables in the top of the stack, to help strengthen it against wind load. These are 3/3" to 1/2" diameter stainless steel cables, brought from points around the perimeter, to a central ring, approximately 10" to 12" in diameter, in the center of the stack. These are to maintain tension all around the top of the stack. However, these cables have a very bad habit of stress cracking, with one end of the cable falling into the fan area. In some cases, the length of the cable and the distance to the fan is such, that the cable actually reaches the fan blades and constantly rubs against the blades or more likely, causes a fan wreck. Therefore, it is important that these cables be checked regularly, kept intact, and/or removed completely.

Determine the thickness, construction, and material of the fan deck. If it is plywood, the thickness should be a minimum of 1" to 1 1/4". Check the condition of the nails, which should be stainless steel. Also, check for delamination. Determine how many layers are delaminating, and over what percentage of the surface of the fan deck. Plywood at times, will get white pocket rot on the underside, but this is not a common malady. The loss of the first one or two plies on top, is not of great structural significance, compared to the total thickness of the deck, even though it looks rugged. Of course, the preferable material is redwood, which avoids this delamination. The major problem with surface delamination, is the safety hazard from stumbling over partially loose material. In some crossflow towers, there are access doors in the fan deck, in order to gain entrance to the distribution deck below. These should be checked for hardware, accessibility, and for proper installation and strength of the supporting framework beneath, to be certain they will support personnel. Also, if it has a rung on top for a handhold, it must be in good condition for safety.

MOTORS

Look for fan motors that are making excessive noise, they may have a bearing going bad. Check for corrosion on the motor, and bell end cover. Be certain the screen is intact on the bell end. If a screen is missing, this presents a dangerous situation with exposed fan blades on the end of the motor. Check the junction box for corrosion and that it is sealed tight. The motor cooling vanes should not have excessive dirt, or scale, as this makes the motor run hot. Motor mount bolts should be secure. Occasionally the seal retainer on the motor shaft is loose. Check that no one motor is running hotter than the rest.

GEARS

Open the access panel in the short vertical wall between the distribution deck and the fan deck, being careful not to lose control of it against the suction. Set it aside and enter the plenum chamber at the distribution deck level, and work your way to under the gear box. Check the gear box to see if it's running excessively hot, noisy, or has scale or corrosion. Gear box mount bolts should be tight. The oil fill lines should be of stainless steel or a suitable rubber or plastic. Be certain there is a flexible braided stainless steel or rubber section between the end of the line and the gear box itself. This prevents vibration accumulating in the oil line, as it extends thru the fan stack, from fatiguing the threads at the gear box, causing failure, loss of oil, and a fan wreck. On the outside, check the oil level in the indicator to be certain that it is at the proper level. Remember, there are two levels that should be marked on every indicator, one for running, and one for off. Look for oil leaks in the gear box and in the gear oil fill line, that may be adding oil to the circulating water, or making oil spots on the fan deck. Oil spots can constitute a fire hazard on the fan deck. Also, leaving containers of new or used oil on the fan deck constitutes a possible fire hazard.

The gear box runs partially full of oil. The upper portion of the gear box is filled with air. Therefore, all gear boxes have a breather, to allow air out or in with temperature change, to maintain atmospheric pressure and prevent blowing seals. This vent coming out the top of the gear box, must be piped thru copper tubing or stainless steel tubing, across under the fan and out the fan stack, and the end bent down, to prevent rainwater entering the gear box. The gear box must breathe dry air in and out, not saturated plenum air. The continued breathing of moisture inside the gear box, can ruin the gears, and bearings.

DRIVE SHAFT

The drive shaft should be checked by looking for a "shadow" effect, indicating that there is an alignment or warped shaft problem. Try to find one fan down, or have one fan turned off for a matter of five to ten minutes, while in the plenum area. Examine the stainless steel or rubber shim packs at both ends of

the drive shaft. The shim packs should not have any of the individual laminations broken. If more than two or three laminations are broken, then the shim pack should be replaced. When replacing stainless steel shim packs, replace the total pack, without rotating any of the individual laminations in the pack.

FAN

While the fan is down, also check for corrosion on the hub, and firm attachment of the air seal. Examine the leading edges of the fan blades, looking for erosion from drift impingement. On cast aluminum blades, look for pitting corrosion. Look for accumulations of scale or other material that can interfere with effective movement of air or cause imbalance. These are the only items for which the fan needs to be down, and it's best to turn it on again. If a fan cannot be turned off momentarily, the air seals can be observed by looking thru port holes in the stack, or from below the fan when checking out the plenum area. The air seals are an important part of the air delivery system. Many mechanics leave the air seals off while working on the fans, so that they can more readily see the condition of the hub and work on the fan in the future. However, this removal of the air seal will occasion appreciable loss in air delivery from the fan and consequent loss of thermal performance, making it essential that they be maintained. Pieces of fiberglass on the fan or distribution deck, or in the plenum, are often pieces of torn up air seals. Always regard the fan as if it were on. Never stand between the blades, extend a hand or any other part of the body into an area where it could be struck, if the fan did come on suddenly. This is an extremely important safety precaution. It is safe to work under a fan, but be certain to remove hard hats, or any other loose items. With head, hands, or any other body parts at a level below the drive shaft, it is a safe operating position.

DRIVE SHAFT GUARDS

Each drive shaft should have two guards, one near the gear box, and one near the motor. These are essential to contain the shaft if the shim pack is lost. Otherwise, the loose end of the shaft can fly into the fan and cause a major wreck. Mechanics have a bad habit of leaving the tops of the shaft guards off, to make it easier to get in and out the next time they have to change the shim pack. These must be checked to be certain that there are two complete, on every shaft, are firmly attached, and if corroded. The best material to utilize for shaft guards is stainless steel.

COUPLING GUARDS

Coupling guards must be checked for corrosion, firm attachment, and possibility of touching or wearing against the drive shaft. This guard protects personnel from the moving coupling outside the stack. Quite often, these guards are loose, and occasionally

rest on the drive shaft. This presents a safety hazard, from both the standpoint of a possible fan wreck, and a fire hazard from the possibility of sparks. For this reason, it is wise to use fiberglass reinforced polyester plastic, or aluminum, to avoid the possibility of sparks.

SPRINKLER

The tower that does not have a sprinkler system, is in an advantageous position. Sprinkler systems are extremely difficult to maintain in an operative condition. Whereas the rest of the tower is usually built with stainless steel, or other corrosive resistant hardware, almost invariably, the sprinkler system is installed with regular mill galvanized steel pipe. This mill galvanize is cut off during installation, at all thread locations. Therefore, the threaded joints in both the sensor lines, and the water lines, rust quickly. To further aggravate this problem, almost invariably, the sprinkler system is hung in the tower with galvanized steel rod hangers. These corrode out, allowing the sprinkler system to sag, break, and trigger false alarms. Many towers have sprinkler systems, either corroded into, or connections pulled apart on 6" and 8" diameter main headers. If a sprinkler system is required, maintain it properly. Use all stainless steel hangers, even stainless steel "plumbers tape" is preferable to the hangers that come with the system. If at all possible, utilize brass or stainless steel pipe and hangers from the beginning. If the system is already starting to corrode, then coat at least all the threaded areas with coal tar epoxy, or mastic. Where the hangers are attached to the 2" x 6" deck joists, the corroding galvanized bolts or lag screws cause iron rot. Many plants are required to have sprinkler systems in the cooling tower, in order to maintain their overall insurance coverage. However, if possible, it is better not to have the fire sprinkler system. The only time that it is effective, is during down time, when the tower is dry. This problem can easily be addressed by stringing regular lawn seep hoses down the fan deck on each side, and in a crossflow tower, down the distribution deck. This will keep the entire structure damp during down time, rather than letting it dry out. This is helpful not only from the standpoint of fire protection, but also prevents excessive drying and loosening of lumber joints. This is particularly important in fir towers, which will shrink, split, and never swell back to original position.

CONDUIT

With metallic conduits, check for corrosion, with plastic conduits, check for brittleness or cracks. This year, inspections have revealed steel conduit completely rusted away from 440 volt lines, going to fan motors, and PVC coated wire exposed with nicks thru the insulation, on the fan deck. They should be either PVC plastic wrapped cables, or aluminum conduit. Even PVC coated steel conduit in cooling tower service, has a tendency to corrode underneath the PVC. In addition to the

regular 440 volt conduits for the fan motor power, also check the conduits for the lighting and other circuits, that may be on top of the tower. Often, clamps on the conduit for the lighting circuits, are corroded away, allowing the conduits to break and hang on the interior PVC coated live wires. Some towers have 110-220 volt outlets on the fan deck, which have broken conduits and exposed PVC coated wires. It is essential for personnel safety, and fire prevention, that all conduit be maintained intact.

VIBRATION CUTOFF SWITCHES

These switches should be mounted on the mechanical equipment support outside the fan stack, somewhere near the foot of the motor. They should not be mounted inside the fan stack, due to almost certain corrosion, that will prevent their proper operation. They should not be mounted on the oil fill line, or any other place which does not represent vibration occurring in the mechanical equipment. Vibration switches should be housed in aluminum or stainless steel. If the switches are the old ball and pedestal type, they should be opened and checked to be sure that when the ball is removed from the pedestal, the mercury switch will trigger. Fully fifty percent of this type, after a few years, corrode to the extent that they are no longer operable. The reset button should always be at the switch location, not remotely wired to the control room. When remotely wired to the control room, most operators, when the vibration switch cuts the unit off, will attempt to reset it two or three times from below, before checking on top the tower for the problem. With the reset button at the mechanical equipment, the operator must be at the source of the problem to reset. Adjustable switches should be set to hold on startup, but trip with more vibration. It is essential to have and maintain operating vibration switches, properly mounted. They will shut down a fan at the beginning of a problem, prior to an actual fan wreck.

MECHANICAL EQUIPMENT SUPPORTS

Most mechanical equipment supports today, are made out of either hot dipped galvanized steel I beams, channel irons, or out of 14"-16" diameter galvanized steel pipe called torque tubes. Any of these materials are satisfactory. They must be checked for tightness of all bolted connections, cracks in any of the weld joints, and for corrosion. A common problem with torque tube supports, is the loss of the seal cap on the outside end of the torque tube. With this cap missing, a large hole is opened directly into the center of the fan area. This results in an appreciable air leak that lowers overall thermal capability.

DISTRIBUTION

Check the condition of the short access ladder between the fan deck and the distribution deck, particularly the oak rungs. If the main distribution header is of redwood stave construction,

check for possible internal rot, although it is rather rare in this area. Check steel bands for corrosion. GRP bands are the preferred material. Look for any major leaks, and check the attachment of the wood pipe to the elbow, coming off the top of the steel riser, for firmness. Be certain that there is a vent at one, and preferably at both ends of the header. This should be a vent with a minimum diameter of four inches to allow air back into the header, during down time, to prevent possible collapse from vacuum. It also allows the escape of entrained air or gases, to avoid water hammer. Measure the height of the water in the standpipe, to determine the pressure on the header. On fiberglass headers, which is the preferred material, check for soundness of wrap joints and tee connections. On steel headers, check for corrosion, particularly at weld joints. Examine the supports under the mains to ascertain that they are secure, and do not have any appreciable wood deterioration. These supports must be in position over framing lines, rather than in between framing components. There are instances where 18" to 24" main headers are supported on double 2" x 4"s on eight foot spans. Insufficient supports and sagging such as this, must be reported and repaired. Also, look for excessively long cantilevered sections of distribution line. If the riser comes up on one side only, there will be crossover lines thru the plenum chamber, to supply water to the other side of the doubleflow crossflow tower. These lines may appear to be satisfactory in the distribution deck area, but be very severely corroded in the plenum area as they cross the center of the tower. They must be checked both outside and inside the plenum area.

VALVES

Although a gear operated butterfly valve is preferable, most valves on crossflow towers are of the rising stem type. Check the stem for corrosion or scale deposits, which will prevent its proper operation. These are the valves utilized to set proper level in all the distribution basins. Lock nuts on stems should be tight. Valves are found with corroded or scaled stems, making them inoperable or even with stems missing completely. This, of course, defeats the entire effort to maintain equal water flow on all cells.

FLOW CONTROL BOX

The flow control box, usually built out of plywood or redwood, equally distributes the flow around the distribution basin, and prevents areas of excessive velocity. Check for delamination of the plywood, and for proper sealants, so that water does not come out the top of the box. A properly constructed and operating flow control box, will have a minimal area where the velocity over the nozzles is so fast, that they do not flow properly. Look for large turbulent areas, extending from the flow control box, to the back wall of the distribution basin. High water level, and/or turbulence, can cause splashing over the top of the basin wall, onto the top of the drift eliminators. This water

then exits the tower as drift. Many crossflow towers have a section of the distribution basin that extends inside the short vertical wall, between the distribution deck and the fan deck. This results in the last 12" to 18" of distribution basin being out of sight. It is necessary to remove the access door in the short wall, in order to see this part of the distribution basin, and determine whether or not any water is flowing over unto the drift eliminators. This overflow is the most prevalent cause of excessive drift in crossflow cooling towers. It often goes unrecognized to the extent that all new drift eliminators will be installed, in an attempt to control the problem, without realizing the actual source. If the cause of the splashover is excessive turbulence coming from the flow control box, then the installation of one or two baffles, to slow the velocity, will solve the problem. If the cause is excessive water depth in the distribution basin, then the most likely cause is plugged distribution nozzles. If after the nozzles are cleaned, the water is still too deep, then the distribution flow control valve must be adjusted to obtain a more satisfactory operating level, or additional, or larger nozzles installed.

NOZZLES

Determine nozzle diameter, pattern, and number, in order to ascertain proper head to obtain design flow rate. Normally, a minimum of 5% to 10% will be plugged, and often over half. These plugged nozzles cause a rise in water level in the distribution basin, resulting in excessive drift loss as described above. Plugged nozzles also create extreme imbalance in the water flow pattern thru the tower and hence appreciable loss in performance. They are plugged by many things, including; mud algae, large pieces of corrosion products from old piping throughout the system, baggies, pieces of polyethylene sheeting, caulking, old bolts, scale, sand, and all sorts of debris. These nozzles can be cleaned quickly and easily and should be checked and cleaned regularly. In a system without proper algae control, the distribution deck will be the primary area of algae growth, and must be cleaned periodically. Plugged nozzles should be cleaned by hand or with a small tool. They should not be opened with the popular steel rod or broom handle, because invariably, the bottom distribution plates are knocked off, and the distribution nozzles become downtake orifices, which lowers thermal performance. In some towers, these distribution nozzles are washed out of position by the velocity of the water. In these instances, they must be fastened down, using two stainless steel nails on each nozzle, which catch the edge of the nozzle under the head of the nails. Some nozzles have a tendency to lose their inside orifice plates, which increases the diameter of the nozzle, lowers the water level in the distribution basin, and results in poor distribution. Sometimes, outside or inside rows of nozzles may be plugged or removed to help prevent ice formation, during winter operation. Quite often, these plugs or missing nozzles

are forgotten, and this portion of the distribution system behaves abnormally during the summer.

The distribution deck floor, is normally constructed of 5/8" plywood. It should be checked for chemical attack and delamination. Very rarely is there any internal rot in this area. The distribution deck walls, are normally made out of 2" x 8"'s or 2" x 10"'s on edge. The outside wall, at or just above the normal operating level of water, is quite susceptible to internal rot. White pocket rot is found in this particular board in many towers, where no other rot is present. Another area very susceptible to white pocket rot, is the double 2" x 6", distribution deck transverse supports, within one foot of where they bolt into the louver column. Just below where this double transverse 2" x 6" is bolted into the louver column, there is a longitudinal 2" x 4", bolted to the louver column, on the face side. This 2" x 4" supports the intermediate transverse 2" x 6" deck joist, between the 4' spaced columns. This is another area where trouble is very likely to develop. The connection between this 2" x 4" and the column, is a single bolt, quite often, without a split ring or a ceramic connecting plate. This 2" x 4" has a tendency to split or sag. If the 2" x 4" splits, sags, or breaks, it allows the center distribution 2" x 6" deck joist to sag, which in turn allows the plywood deck to pull apart at the joints, and in extreme cases, pull loose completely. One tower inspected last year, had this problem, where one sheet of plywood pulled loose to the point that it collapsed onto the top layer of fill, one foot beneath. This collapse, under a mans' foot, convinced the owner that the entire tower had become weakened and unsuitable for service, and he was in the process of pricing a new tower. The inspection, of course, revealed the source of the problem, and the major repair involved running a new 2" x 6", double bolted, longitudinally down the sides of the top of the louver columns, to support the intermediate joists. Crawl over the outside distribution wall very carefully, using the top louvers at their intersection with the louver column, for support. Do not put weight in the middle of the louver. This position will allow an examination of the underside of the distribution deck, the nozzle pattern, the redistribution deck (if any), and the determination of fill and hanger condition, and ice damage, in the upper two cubes. This also will afford an additional look at the upper louvers compared to the lower louvers. Come back over the outside distribution deck wall, and check the distribution deck walkways for internal fungus attack, and excessive algae, which can constitute a safety hazard.

PLENUM CHAMBER

The plenum chamber in a crossflow tower, is the large V shaped area between the drift eliminators. It is the area that is most subject to internal fungus or white pocket rot. Therefore, it must be examined thoroughly with a probe instrument (awl). This area also must be checked for iron rot, excessive algae,

tightness of joints, etc. If examination of the drift eliminators and lower framework, by probing near the center catwalk, at the bottom of the tower, indicates the tower does not have extensive white pocket rot, then the easiest procedure physically, is to enter the plenum chamber from the access door, in the short wall at the distribution deck, on top of the tower. If the tower does have appreciable internal rot and many weakened members, then safety dictates that the inspection begin at the bottom. In this situation, each set of framework six foot above the inspectors current footing, can be probed and a determination made concerning its soundness, before it is depended upon for support, during the climb up thru the framework. Regardless of the point of entry, care must be taken while crawling thru this plenum area, not to slip or fall. When changing levels (these towers are framed in six foot vertical increments), always stay near the drift eliminators. This will provide an added safety factor, in that there is a surface to catch if a slip is made, rather than open framework. At the top level, probe the underside of the fan deck, looking for internal fungus attack. Check the inside distribution basins to see that they are not overflowing, on top of the drift eliminators. Look thru the drift eliminator seals, or the drift eliminators themselves, at the top inside fill to ascertain its position and condition. Probe the framework members for internal fungus attack. Pay particular attention to joint areas and areas around unused bolt holes, which are favorite entrance locations for internal fungus attack. Another specific area in which to detect early internal rot, is the double transverse 2" x 4" ties as they penetrate the drift eliminators. In most cooling towers, the upper third of the tower will be the first area to suffer internal rot, or will have the most advanced internal rot. This of course, is the highest part of the tower, so extreme care must be taken while inspecting in this area.

If the drift eliminator slats are wood, check them for internal rot and surface attack. Internal fungus attack is quite prevalent in the wood slats, in the upper third of the tower. In the herringbone type design, there is a 2" x 3" horizontal support member, every three vertical feet, in the drift eliminators. This horizontal member is quite often infected with internal fungus attack. While checking the drift eliminators, also check the supports, which most of the time will be notched plywood. This plywood is very susceptible to internal fungus attack and to delamination. If the drift eliminators are PVC or other plastic, check to see that they are all in position, and the holders are properly attached to the support 2" x 4" framework. Older wood drift eliminators have cast iron holders, which are subject to extreme corrosion. Check wooden transverse partition walls in the plenum area, for surface attack, and internal rot. Check wooden and GRP (the preferred material) walls for proper fastening. Quite often, panels, particularly in the upper section of these transverse partition walls, will be

knocked out of position, due to failure of fasteners. It is important to keep all of these panels in position, so that when maintenance requires one fan to be down, the adjacent fans do not draw all their air thru the resulting hole. The access doors thru these transverse partition walls, on the lower walkway, often have iron or steel hardware, which corrodes severely and makes them inoperable. They then remain open or missing. It is important that these doors remain operable so that they can be opened and closed during inspection and maintenance. They should be closed in normal operation, to prevent bypassing of air from a down cell to an operating cell. All hinge hardware on these doors, should be stainless steel. Most newer crossflow towers do not have a longitudinal partition wall. This probably causes a slight reduction in thermal performance, but not of sufficient magnitude to justify the expense of installing the wall. In examining the framework in the plenum chamber, it is extremely important that the structural integrity of the horizontal support members and vertical columns, directly under the mechanical equipment, be verified. Often inspection reveals severe deterioration in the very members that are holding up the mechanical equipment support, and consequently the dead weight of the mechanical equipment, plus the downward thrust of the fan. Another further check to be made in some designs of crossflow towers, is that the columns, particularly those directly under the mechanical equipment, be maintained in direct alignment from section to section. This design has splices with single bolt connections in each end of the two sections of columns. This allows columns to move in one direction and get off center. In these cases, splice blocks should be added on the loose side, and/or double bolting employed to prevent movement in this joint. The walkway itself, at the bottom of the plenum chamber, needs to be checked for internal fungus attack in the 2" x 4" treads. It is also wise to have a handrail on this walkway, inasmuch as it will encourage traversing the walkway by your operators, and thereby result in their discovering problems. This is one of the better vantage points from which to check spider cables, air seals, and other portions of the mechanical equipment overhead, in addition to drift eliminators, and possible sources of excessive drift.

COUNTERFLOW (ONLY DIFFERENCES FROM CROSSFLOW WILL BE COVERED)

Measure the distance from the underside of the fan deck to the top of the drift eliminators, to determine how much plenum area you have which influences pressure loss thru the plenum area. The distance from the drift eliminators to the centerline of the distribution will indicate how much disengagement room is available to reduce drift loss. The distance from the centerline of the distribution to the top of the fill, will help determine whether or not there is adequate room for the distribution spray to form an interlocking grid, prior to reaching the top of the fill. The number of decks of fill there are below the top of the air inlet louvers, and the distance from the basin curb to the

first layer of fill, should be recorded. The condition of the louver drain board at the top of the louvers, must be checked.

LOUVERS

Counterflow louvers normally are smaller and closer together than those in a crossflow tower. In more recent model counterflows, louvers are often left out completely. This is to reduce total static thru the tower, and increase performance. As long as the drain board at the top of the air inlet opening area, is properly fitted, this is a satisfactory arrangement. With this type of design, the cold water basin is normally one or two feet wider than the outside dimensions of the tower. This insures containing all the water in the basin. In counterflow towers with no louvers, maintaining the center longitudinal windwall is important to reduce loss of water on the leeward side, which is called windage.

CASING

The casing on counterflow towers, is similar to the end walls on crossflows, but covers four sides above the louvers. There are more of these towers in existence that have the old style double redwood wall casing. Many have what is referred to as an aerator casing, that is a solid wall on the outside of the perimeter columns constructed of 1" x 6" horizontal boards, and then a second wall constructed of 1/2" x 4" boards vertically mounted in a louvered fashion. In this design tower, the location of the white pocket rot is almost invariably in the inside casing, from a foot or two above the drift eliminators to below the drift eliminators and sometimes on down to the air inlet louvers. This is the only portion of the tower in the flooded section, that can have white pocket rot. This is possible because, although one side of the 1" x 6" is flooded, the outside is dry, and consequently in the center of the board, there exists a condition with sufficient moisture for white pocket rot, without being flooded. The white pocket rot that starts in this area, has the bad habit of working its way into the face side of the perimeter columns, thereby weakening the framework. A very careful search, above and below the drift eliminators, must be made for this rot. Normally, when this internal rot is detected, a minimum of 15% to 20% of the perimeter columns will have appreciable attack in their face side, and must be replaced when this double wall casing is removed and replaced with a single wall of GRP.

BASIN

The basin has all the same characteristics as crossflow, except that increased clear distance between the surface of the water and the bottom fill layer, affords the inspector adequate room to walk throughout the basin area to check carefully for hot and cold spots, mud, etc.

FILL

This clearance, also gives an opportunity to check lower fill racks for possible collapse due to deterioration or ice loading. Many counterflow towers are built with a film pack fill. This is a fill constructed of formed thin sheets of PVC, glued together, that makes it a very effective heat transfer surface. Particular attention must be paid to film pack fill to determine whether there is any appreciable pluggage, caused by algae, mud, scale, etc. These are very efficient towers, but the fill area must be maintained in a clean condition.

FAN STACKS

There are more existing redwood stacks in counterflows, and many of them are of the earlier design with straight walls, rather than the velocity recovery type. Close examination for internal fungus attack must be made.

FAN DECK

A counterflow tower has relatively more fan deck per cell, than a crossflow, inasmuch as the fan deck in this case covers the entire top of the tower. The fan decks in counterflow towers are usually made of redwood, rather than plywood. This material is usually in good condition on the top side. However, the underside, including fan deck joists, must be checked carefully for white pocket rot.

PLENUM

Access to the plenum area is thru a trap door in the fan deck. The entire plenum area, which in this case is a horizontal area ranging from a minimum of four feet, to a maximum of seven feet in vertical height, must be checked thoroughly for white pocket rot. This can be done with considerably less agility than required in a crossflow, inasmuch as all the movement is in a horizontal direction. Even if the drift eliminators, upon which the inspector is crawling, are deteriorated to the point of collapse, it is usually only a short distance to the distribution system.

The drift eliminators have to be checked for surface attacks, white pocket rot, and particularly for fouling by algae, mud, and scale, etc. Plywood holders must be checked for delamination and rot, and the support 2" x 4"'s beneath checked for internal rot. Individual slats or bundles fallen out of position, should be noted.

The plenum partitions extending between the drift eliminators and underside of the fan deck must be maintained intact to prevent air leakage between cells, when all cells are not in operation. These panels, usually 4' x 6' have a tendency to fall out of position, due to fastener failure. They should be replaced with 8 oz. corrugated GRP, when they become rotten or loose. They are originally constructed of 1/2" to 3/4" thick redwood boards.

All plenum framework, between the drift eliminators and fan deck, must be checked carefully for internal white pocket rot, and if galvanized hardware is involved, for iron rot. The support members, directly under the mechanical equipment, must be examined carefully, including detection of any swaying or excessive movement, which may indicate the possible need for additional diagonal bracing.

DISTRIBUTION

Access from the plenum chamber to the distribution, is thru a second trap door, in the drift eliminators. Both the first and second trap doors must be sturdy enough to support a man. The access ladder from the fan deck to the distribution area, should be checked for white pocket rot. This ladder usually extends a few feet into the distribution area. The distribution must be checked in full operation. This is the only method that will reveal plugged nozzles, flow patterns, and complete fill coverage. This is extremely important in the case of film pack fill, inasmuch as all areas must be wet on top if maximum performance is to be obtained. Check for nozzles blown out of the laterals, and laterals blown out of the main. In redwood stave mains, check the condition of the lumber, and look for corrosion or breakage in the bands, many of which were originally made of galvanized steel rods. They should always be replaced with stainless steel rods or banding. There may be standpipes on the main headers, however they are not absolutely necessary in counterflows, as all the open nozzles prevent any formation of vacuum during down time. All steel pipe has to be checked for corrosion. Any cleaning of plugged nozzles or laterals, must be done with the tower on line, in order to provide the pressure necessary to dislodge the obstructions. Many plants, when informed that the distribution must be cleaned with the pressure on, then suggest turning the fan off for safety. However, this makes the working conditions intolerable, due to lack of breathing air and increased temperatures in the distribution area. The workmen are below the drift eliminators, where they are quite safe from the fan. Therefore, the safest and most practical procedure, is to leave both fan and water on, and operate in a normal manner.

GENERAL

This thorough inspection of the cooling tower should be supplemented with a complete description of the water treating program being utilized, and circulating water analysis, so that a definitive opinion can be formulated, as to the cause of the various types of deterioration encountered in the cooling tower. A sketch should be made locating the north arrow, numbering the cells, and locating risers, pumps, makeup lines, etc. When references are made to locations of various faults, this will prevent confusion between inspector and those utilizing the report.

Following this thorough inspection, a report should be issued covering all pertinent findings. Recommendations should be made, where appropriate, to correct defects. These recommendations should be summarized in such a fashion, as to indicate the more immediate requirements, the less urgent matters that can be done in the next few months or year, and those areas that may need to be replaced in the future, but have several years of useful life left. This procedure will help in formulating appropriate budget requests, at the right times. Any recommendations effecting performance capacity or safety, should be identified.

As stated in the opening of this paper, the continued safe operation of the cooling tower at its optimum performance capacity, is essential for maximum unit production of electricity, gasoline, polyolefins, etc. Therefore, a thorough inspection, as described in this paper, is an essential part of proper operation and maintenance of plant equipment.