Counterflow Natural Draft Cooling Towers
For Electric Power Generating Plants

by

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I. THE HISTORY OF AMERICA’S HAMON/RESEARCH COTTRELL COUNTERFLOW NATURAL DRAFT COOLING TOWERS

Most of the existing counterflow natural draft cooling towers constructed in U.S. power plants, beginning in the mid-1960s and continuing to the present day at Georgia Power’s new nuclear Units 3 and 4 at the Vogtle Nuclear Power Plant, were constructed by Research Cottrell in New Jersey under license agreement with the family-owned Belgian company, Hamon (pronounced Hāˈmōn’). To date, Hamon/Research Cottrell has constructed 61 counterflow natural draft cooling towers in the United States. Because of the predominance of Hamon natural draft cooling tower technology in the U.S. power generation arena, we will review the evolution of their counterflow designs over the years and describe tried-and-proven methodologies for maintaining and enhancing the thermal performance characteristics of these cooling towers.

In 1904, Achille Hamon, an engineer from Brittany in France, created a company in France (Hamon France) that designed and built wood-structured natural draft cooling towers. Two years later, Achille’s brother, Fernand Hamon (also an engineer), started a similar cooling tower company in Belgium (Hamon Belgium). In 1958, Fernand’s son, Maurice Hamon, who had become the head of both companies, granted a license to the American company, Research-Cottrell, to market and construct Hamon cooling tower designs in the United States.  

By 1960, Hamon’s counterflow natural draft cooling tower designs utilized non-combustible materials, including reinforced concrete structures and asbestos-cement film-type fill, lateral distribution piping, and blade-type drift eliminators. Although it was not until 1963 that Research-Cottrell was awarded their first cooling tower order, they would eventually construct fifty-four asbestos-cement-filled counterflow natural draft cooling towers in twenty-six different U.S. nuclear and fossil power plants between the years 1966 and 1984. Hamon/Research Cottrell natural draft cooling towers constructed after 1984 did not use asbestos-containing materials.

Although the asbestos-cement components in some of the cooling towers have been replaced over the years with plastic or fiberglass components, at least thirty-one of the original fifty-four towers continue to provide water cooling service at eighteen U.S. power plants utilizing original asbestos-cement internal components.

In this continuing education course we will review the requirements for proper maintenance of these 35 to 50-year old U.S. counterflow natural draft cooling towers, including those towers that no longer include asbestos-cement internal components. Because the designs of the asbestos-cement fill, drift eliminator, and lateral water distribution piping systems of the cooling towers are unfamiliar to many engineers, we will begin with a description of the original asbestos-cement internal components and how they are configured within the cooling tower. Also included in the descriptive information is a brief discussion of the evolution of the design that occurred over the eighteen-year time span that the cooling towers were constructed in U.S. power plants.
The maintenance requirements for the cooling tower fill system, water distribution system, and drift eliminator system are addressed separately, providing recommended system inspection protocols, highlighting commonly encountered anomalous conditions, and providing recommended repair and renovation methodologies.

II. DESCRIPTION OF THE COOLING TOWER FILL SYSTEM DESIGN

The fill system of the Hamon/Research Cottrell cooling tower design is comprised of multiple tiers of 16-inch high by 0.165-inch thick asbestos-cement fill sheets of various lengths (see Figure 1). As seen in the elevation view, each asbestos-cement fill sheet includes shoulders to facilitate suspension on precast concrete beams. The shoulders of fill sheet tiers number I, III, and V are suspended directly on top of precast concrete fill support beams; whereas fill sheets tiers number II, IV, and VI are inverted and bottom supported on top of the fill sheet tiers directly below them. Although there are a variety of fill sheet lengths in each cooling tower, the nominal fill sheet length in 1960s and early 1970s vintage designs is approximately 8 ft.-6 in. (2590 mm). In the late 1970s and later, nominal fill sheet lengths are approximately 10 feet (3048 mm).

The depth of the fill (number of tiers of fill sheets) varies within the cooling tower, with only two to four tiers of fill sheets at the outer perimeter of the fill system and with the deepest fill (six to eight tiers of fill sheets) adjacent to the shallow perimeter fill. The depth of the fill system then gradually steps down radially towards the center of the cooling tower fill system.
The spacing of the fill sheets varies from cooling tower to cooling tower and within each cooling tower, with closer spacing at the perimeter and wider spacing near the center of the fill system. The spacing of the asbestos-cement fill sheets is maintained through usage of plastic spacer combs. The spacer combs are installed between the tiers of fill sheets and on top of the uppermost tier of sheets as shown in Figure 2.

The center-to-center fill sheet spacings used in U.S. cooling towers include 1.122 inches (28.5 mm), 0.984 inches (25 mm), 0.886 inches (22.5 mm), and 0.787 inches (20 mm).

The spacing of the lowest tier of fill sheets is maintained through usage of tubular-shaped “struts” (Figures 3, 4 and 5) that are inserted into holes that are pre-drilled into every other fill sheet.
III. DESCRIPTION OF THE WATER DISTRIBUTION SYSTEM DESIGN

The design of the water distribution system of the counterflow Hamon/Research Cottrell natural draft cooling towers built in the United States in the 1960s is significantly different from the 1970s and 1980s-vintage asbestos-cement-filled cooling tower water distribution system designs. As seen in Figures 7 and 8, the water distribution system design of the cooling towers built in the 1960s included a parallel pair of deep, narrow water distribution flumes that each receive their water flow allocation from a single riser pipe located at one end of each flume. In this configuration, no fill sheets are installed underneath the flumes and no nozzles are installed in the floor of the flumes. These earlier cooling tower designs also include manually operated flume de-silting valves that facilitate removal of mud accumulations in the water distribution flumes.

With reference to Figure 9, the water distribution systems of the Hamon/Research Cottrell natural draft cooling towers constructed in the United States in the 1970s and 1980s include wider, shallower water distribution flumes. In this configuration, fill sheets are installed underneath the flumes, nozzles are installed in the floor of the flumes and no de-silting valves are installed in the flumes. The riser pipes are manufactured from cast-in-place reinforced concrete pipe that interface with the water distribution flumes at each flume midpoint. The risers penetrate the fill system as shown in Figure 6.

![Figure 6: Riser Pipe Penetration Through the Asbestos-Cement Fill System](image-url)
Figure 7: Water Distribution System Design of Hamon/Research Cottrell Counterflow Natural Draft Cooling Towers Constructed in the 1960s
Figure 8: Narrow, Deep Water Distribution Flume in 1960s Hamon/Research Cottrell Towers

Figure 9: Wide, Shallow Water Distribution Flume in 1970s and 1980s Hamon/R.C. Towers
It is recommended that the open area through the fill system adjacent to the riser penetration be closed off with a stainless steel or plywood seal in order to prevent short-circuit airflow through the opening.

The lateral water distribution piping in all fifty-four cooling towers of this type were originally manufactured from asbestos-cement. The inside diameters of the “Transite pipes” (originally a Johns-Manville trade name that, over time, became a generic name for asbestos-cement) used in the cooling towers includes 14-inches, 12-inches, 10-inches, 8-inches, and 6-inches. The wall thickness in all Transite pipe sizes is usually ½-inch. Transite pipe couplings, that include two elastomeric internal o-rings, are used to connect the pipe sections (see Figure 10).

The arrays of lateral water distribution piping are suspended from precast concrete beams using stainless steel pipe hanger assemblies.

Spray nozzles are attached to the underside of the Transite pipes via 2½-inch diameter pre-drilled holes. The original design of the Hamon/Research Cottrell cooling towers used thin-walled plastic threaded rings to adapt the nozzle assemblies to the pipes. Today, most of the plastic threaded rings have been replaced with plastic lateral-eared adapters that are secured to the Transite pipes using stainless steel worm-gear-type hose clamps or banding and bandit buckles.

The orientation of the lateral distribution piping with respect to the fill is shown in Figure 11.
IV. DESCRIPTION OF THE DRIFT ELIMINATOR SYSTEM DESIGN

The drift eliminators originally used in all fifty-four Hamon/Research Cottrell counterflow natural draft cooling towers were manufactured from standard 0.236-inch (6 mm) thick corrugated asbestos-cement European roofing panels. The so-called “Toschi Wave” drift eliminators (named after the German fiber cement manufacturer that pioneered the usage of asbestos-cement as a cooling tower material) are assembled in panels comprised of eight individual 7-inch high blades using plastic spacers and stainless-steel hardware (see Figure 12).

Figure 11: Interior View of the Asbestos-Cement Fill System and Lateral Water Distribution Pipes

Figure 12: Toschi Wave Asbestos-Cement Drift Eliminators
The nominal center-to-center spacing of the individual drift eliminator blades is 2-inches (50.8 mm). In salt water cooling towers, the drift eliminator blade center-to-center spacing is reduced to 1.2 inches (30.5 mm). The drift eliminator panels are usually bottom-supported on the precast concrete beams from which the lateral distribution pipes are suspended. However, in some early designs of the 1960s, the drift eliminator panels are bottom-supported on a separate set of precast concrete beams located at an elevation that is 7-feet above the elevation of the pipe support beams (and 7-feet above the flume walkway elevation).

V. ASBESTOS-CEMENT FILL SYSTEM MAINTENANCE

V.A. Water Quality Considerations

Until about 1982, nearly every natural draft cooling tower constructed in the United States and Western Europe utilized flat or corrugated asbestos-cement sheets as the material of choice for film-type or splash-type fill material, drift eliminators, water distribution piping, inlet louvers, and wind walls. The popularity of asbestos-cement as a cooling tower material of construction was a result of its relatively low cost, its non-combustibility and its durability. Some cooling towers in Germany, for example, have been in service for more than 60 years with little or no degradation of the original asbestos-cement fill systems. However, in the United States a few large asbestos-cement filled cooling towers have experienced whole-scale structural failure of the thin asbestos-cement sheets that comprise the fill systems.

In 1986 and 1987, a study conducted by Southern Company Generation determined that the observed delamination and general deterioration of asbestos-cement cooling tower fill sheets was, in some cases, caused by water chemistry that was not compatible with the Portland cement substrate of the asbestos-cement material. It was noted also that the water chemistry that attacks the Portland cement of the asbestos-cement fill material also attacks the Portland cement of the concrete cooling tower structural members. The Southern Company study characterized the aggressiveness of cooling water chemistry in terms of the Langelier Saturation Index.

The Langelier Saturation Index, or LSI, is used as a measure of the carbonate stability or scaling tendency properties of cooling water. A negative value for the LSI indicates that the water will dissolve CaCO3 (calcium carbonate) and may leach calcium from asbestos-cement. When the LSI is equal to zero, the water is in equilibrium with solid CaCO3. When the LSI is positive, the water is supersaturated with CaCO3 and may deposit scale on the surfaces of the cooling system.

Another index commonly used to indicate the scale "dissolving" or scale "depositing" tendency of cooling water is the Ryznar index. A Ryznar index value of less than 6 indicates a scaling tendency, whereas a Ryznar index value of greater than 7 indicates a corrosive tendency.
Loss of calcium from asbestos-cement fill sheets and drift eliminator blades results in a loss of strength. Calcium is leached from Portland cement by dissolution of free lime, Ca(OH)$_2$, and by ion exchange from the calcium silicates, Ca(-O$_3$SiO)$_2$, which provide most of the strength in Portland cement.

Free lime dissolution: \[ \text{Ca(OH)}_2 = \text{Ca}^{+2} + 2\text{(OH)}^- \]

Ion exchange: \[ \text{Ca(-O}_3\text{SiO)}_2 + 2\text{H}_2\text{O} = (-\text{O}_3\text{SiOH})_2 + \text{Ca}^{+2} + 2\text{(OH)}^- \]

In order to protect asbestos-cement cooling tower components from chemical attack, it is necessary to maintain water quality parameters within specified limits. More specifically,

- In order to prevent leaching of calcium from the Portland cement in asbestos-cement components, without scaling of the condenser tubes, a positive LSI (Langelier Saturation Index) must be maintained simultaneously with a Ryznar Stability of 6 or more. This means that the LSI may range from 0 to 1.0 for a cooling water pH of 8, or from 0 to 1.5 for a pH of 9. Usually these indices can be controlled by blowdown (continuous disposal of a portion of the circulating water), but sometimes acid or alkaline substances may be needed.

- In order to prevent sulfate attack of the Portland cement in concrete and asbestos-cement fill, the following sulfate limits are recommended for the various "Types" of Portland Cement used in the manufacture of fill sheets and drift eliminators:

<table>
<thead>
<tr>
<th>Recommended Sulfate Limits SO$_4$ (mg/l)</th>
<th>Portland Cement Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 150</td>
<td>I</td>
</tr>
<tr>
<td>150 – 1500</td>
<td>II</td>
</tr>
<tr>
<td>1500 – 10,000</td>
<td>V</td>
</tr>
<tr>
<td>Over 10,000</td>
<td>V + Pozzolan</td>
</tr>
</tbody>
</table>

Sulfate attack is unlikely in freshwater systems unless the system is zero discharge or uses large amounts of sulfuric acid.

- Calcium carbonate scale inhibitors, classified as crystal solubilizers (including phosphonates, polyphosphates, and polyacrylates) often attack asbestos-cement fill systems when applied at the concentrations normally used in circulating water systems. By using smaller concentrations of scale inhibitor, it is possible to prevent calcium carbonate scaling without damaging the fill. For example, 0.3 ppm of phosphonate may be applied, instead of the recommended 1.5 ppm, for cooling water with a Ryznar Stability Index of 5.8.
V.B. Delamination Prevention

In North America, asbestos-cement cooling tower fill sheets were produced by 5 manufacturers:

1. Atlas Turner
2. Johns Manville
3. Celotex
4. Phillip Carey
5. GAF

The quality of the fiber cement product manufactured by these five American and Canadian companies varied considerably. Utility cooling tower experience over the past 45 years has established that Atlas Turner produced the best quality fill sheets and GAF produced the poorest quality fill sheets. GAF fill sheets have experienced catastrophic delamination failure in a number of counterflow natural draft cooling towers (Figure 13).

There is substantial evidence that the severity of fill sheet delamination, in general, is related to poor water distribution, particularly when improper water distribution is caused by spray nozzle fallout problems. In very cold weather, poorly wetted fill sheets can freeze overnight and then thaw during the daytime when ambient temperatures increase. The repeated freeze-thaw cycle, then, creates the internal stresses that give rise to fill sheet delamination.

Figure 13: Mud-filled Delaminated GAF Fill Sheets
From this, it may be deduced that one way to minimize the potential for fill sheet delamination is to ensure that all of the spray nozzles are securely attached to the lateral distribution pipes. Furthermore, any anomalous conditions that give rise to isolated areas of low fill water loading should be eliminated.

V.C. Maintenance of Fill Sheet Spacer Combs

As mentioned previously, the spacing of fill sheets is maintained through usage of plastic spacer combs installed between the tiers of fill sheets and at the top surface of the fill system. For optimum cooling tower thermal performance efficiency, the tiers of fill sheets must be straight and aligned one above the other. Bowed or leaning fill sheets obstruct airflow. When walking on asbestos-cement fill sheets, daylight should be visible through the fill system. Because many asbestos-cement-filled natural draft cooling towers are now 40 – 50 years old, the plastic fill sheet spacer combs have become brittle with age and can be easily broken by foot traffic (Figure 14).

![Broken Fill Sheet Spacer Combs](image)

Broken spacer combs should be replaced before the top tier of fill sheets begin to lean over and become permanently bowed. When replacing broken spacer combs, it is necessary to remove any small pieces of the combs that may have fallen through to the next lower fill tier. Rubber mallets should be used to hammer the combs into place. It is also important that the spacer comb teeth with serrated surfaces be facing downward (biting into the sheets), leaving the smooth surfaced spacer comb teeth facing upwards.

V.D. Loss of Bottom Tier Fill Sheets: Repair Recommendations

As mentioned previously, the spacing of the lower portion of the fill sheets in the bottom fill tier (Tier I) is maintained through the use of small plastic spacer buttons (“struts”). Every other fill sheet in the bottom tier includes 2, 3, or 4 (depending on the length of the fill sheet) pre-drilled 7/16-inch (11.1 mm) diameter holes to accommodate the struts.
Because the plastic spacer struts are tubular in cross section (Figure 15), after a number of years of operation, the struts act as “cookie cutters” and punch holes in adjacent fill sheets. The cookie cutter action is caused by flow induced vibration of the bottom tier of sheets, which is particularly significant in high wind conditions and during winter operation when the rate of airflow through the cooling tower is greater. Once the struts have punched holes completely through adjacent fill sheets, the bottom portion of the Tier I fill sheets become unconstrained (free floating), resulting in a pairing off of the fill sheets (see Figure 16).

The pairing of fill sheets reduces cooling tower thermal performance efficiency by restricting airflow into the fill system. Furthermore, because the “punched” bottom tier of fill sheets become free to move about, cracks begin to form at the fill sheet shoulders, leading to fill sheet fallout and leaning and bowing of the entire bay of bottom fill sheets (Figure 17). Because the second tier of fill sheets (Tier II) is supported by the bottom tier (Tier I), loss of fill sheets in Tier I eventually leads to loss of fill sheets in Tier II (Figure 18).
In those Hamon/Research Cottrell cooling tower designs that include only three tiers of fill sheets in the central region of the fill system (Figure 19), loss of the two lowest tiers of fill sheets, in the manner described above, can create an extremely hazardous condition to maintenance personnel. *It is never safe to walk on a single tier of fill sheets.* Furthermore, if the Tier III fill sheets are bowed and leaning over, maintenance workers may be unaware of the existing fall hazard.

Replacement of missing Tier I and Tier II fill sheets with new asbestos-free fill sheets is fairly labor intensive, requiring that the tiers of fill sheets above the damaged area be removed to form a “stair step” cavity (Figure 20) in order to facilitate safe access to the damaged bottom tiers of fill sheets. More often, however, the fill system repair involves removal of *all* of the fill sheets within the fill bay (the rectangular plan area bounded by four precast concrete columns), installation of new pultruded FRP (fiberglass reinforced polyester) fill support beams, and installation of an appropriate depth of new PVC fill modules.
V.E. Perimeter Fill Bay Renovation

Fill sheet fallout problems in perimeter fill bays (the fill bays immediately adjacent to the cooling tower shell) are very common. There are two main causes of fill sheet fallout in perimeter fill bays:

1. Many perimeter bay fill sheets are field cut to length and the quality of the field cut fill sheet support shoulders is subject to the skill and workmanship capability of the installer (see Figure 21).

2. There is relative movement between the cast-in-place concrete cooling tower shell and the interior precast concrete fill support structure due to thermal expansion and contraction. This movement causes a grinding action between the perimeter ends of the fill sheets and the concrete fill support pockets that are cast into the inside of the shell wall. In time, this grinding action can erode away the edge of the support pocket or cause the field cut fill sheet shoulder to crack and fail. The thermal expansion and contraction between the shell and the interior precast concrete structure can also cause damage and structural failure to the ends of precast concrete fill support beams (Figure 22).

Figure 20: Stair-Step Configuration Created to Provide Safe Access to Lower Tiers of Fill Sheets

Figure 21: Field Cut Perimeter Fill Sheets
Because fill sheets installed in the outer perimeter of the cooling tower fill system are, in general, very unstable, it is recommended that maintenance personnel avoid crawling over perimeter fill sheets, unless each person is securely tied off to a precast concrete pipe support beam or column or engineered tie-line. Transite pipes are very brittle and should never be used as a tie-off point. A “perimeter” fill bay can easily be identified as a fill bay that is not bounded by four precast concrete columns. Perimeter fill bays are typically odd-shaped (not rectangular).

Maintenance and repair of perimeter fill bays using asbestos-free fiber cement fill sheets is very expensive and subject to recurring problems. For this reason, the best option for regaining the lost cooling tower thermal performance efficiency caused by damaged perimeter fill bays, and for reducing the maintenance costs associated with fill sheet fall-out problems, involves replacement of fill sheets with lightweight, low-fouling PVC fill modules, bottom-supported on new pultruded FRP support members (Figure 23).
Key to the successful implementation of the perimeter fill system design modification is the quality of the PVC fill installation workmanship. At the perimeter of the cooling tower fill system, where the inflowing cool ambient air experiences a minimum of rain zone pre-heating before entering the underside of the fill, short-circuit ambient airflow through holes in the fill system can result in significant reductions in cooling tower thermal performance efficiency (Figure 24). For this reason, it is essential that the PVC fill modules be sculpted to match the three-dimensional contour of the cooling tower shell (Figure 25).

Figure 24: Poor Fill Installation Workmanship in Perimeter Fill Bay

Figure 25: Example of Quality PVC Fill Installation in Perimeter Fill Bay
V.F.  Workmanship Issues in Fill Sheet Installation

Fill system inspections conducted by the writer over the years have revealed extensive fill sheet bowing and warpage in some counterflow natural draft cooling towers. In these cooling towers, no daylight can be seen through the fill system, indicating very poor alignment of the tiers of fill sheets one above the other. This anomalous condition exerts a negative impact on cooling tower thermal performance and gives rise to severe multi-tier fill sheet fallout problems within interior fill bays. It has been well established that fill sheet bowing, leaning, and warpage on such a widespread scale is not age-related, but is, rather, a consequence of poor fill sheet installation workmanship in the vicinity of the H-columns that penetrate the fill system. Fill sheets that are installed between the posts of an H-column are, by design, reduced in length in order to avoid interference with the posts (Figure 26).

![Figure 26: Properly Cut Fill Sheets between H-Columns](image)

However, as seen in Figure 27, fill sheet installers sometimes intentionally bowed fill sheets to be installed in the vicinity of H-columns, using plastic spacer combs to maintain the errant configuration. By bowing the fill sheets near the H-columns, the number of asbestos-cement fill sheets that required cutting in the field was minimized. This unfortunate practice appears to be more common in cooling towers constructed in the 1980s when the hazards associated with cutting asbestos-containing materials were firmly established. The stresses created within the bowed fill sheets near the H-columns are transferred to adjacent sheets, propagating, in time, to the entire fill bay. The end result is a fill bay comprised entirely of bowed, misaligned fill sheets (Figure 28). In those instances where the entire asbestos-cement fill system is corrupted by this workmanship issue, replacement of the entire fill system is sometimes necessary.
Figure 27: Intentionally Bowed Fill Sheets at H-Column

Figure 28: Propagation of Fill Sheet Bowing From an H-Column
VI. WATER DISTRIBUTION SYSTEM MAINTENANCE

VI.A. Inspection for Nozzle Damage and Pluggage

One of the most insidious causes of cooling tower thermal performance deficiency is pluggage of nozzles with mud and debris. Oftentimes the only way that nozzle pluggage can be detected is by removing the nozzle and visually inspecting the interior of the nozzle cone. Exit air mappings can also be used as a means of isolating nozzle pluggage.

The large blue-colored area seen in the right-hand side of this cooling tower exit air temperature mapping (Figure 29), for example, is symptomatic of large-scale nozzle pluggage. Nozzle pluggage creates areas of insufficient fill water loading which appear as paths of least resistance to the cool inflowing airstream and manifest as high velocity, cool airstreams exiting the drift eliminators. Because nozzle pluggage exerts a significant impact on thermal performance efficiency, the man-hours required to inspect nozzles can be easily justified. The process of inspecting natural draft cooling tower nozzle arrays for damage or pluggage with mud or debris can be accomplished by one person over a 2 or 3-day period for a moderately sized natural draft cooling tower. Experience has shown that nozzle pluggage occurs most frequently in lateral pipes fed from the last riser/flume downstream from the primary hot water inlet header connection.

Each plugged, missing, or broken nozzle should be flagged with red-colored survey ribbon and marked on a plan view drawing to facilitate easy identification and documentation for maintenance personnel (Figures 30 and 31).

Flume nozzle pluggage is a common problem because silt and mud tend to accumulate near the ends of the flumes. Flume nozzle pluggage may be minimized by implementing the following design modifications and maintenance procedures:
• Perforated stainless steel flume nozzle filters should be installed over each flume nozzle to prevent debris from entering the nozzles (Figure 32). Usage of PVC standpipes to elevate nozzle entrances cannot prevent flume nozzle pluggage (Figure 33).

• Flumes and flume nozzles should be inspected and cleaned every maintenance outage.

• Cooling tower nozzle orifices should be at least 1.0 inch (25.4 mm) in diameter.

• Avoid using branched flume nozzle assemblies as shown in Figure 34. It is better to use a single full-cone spray nozzle in each flume nozzle hole.
Figure 31: Inspection Drawing Depicting the Locations of Plugged Nozzles and Other Anomalous Conditions
VI.B. **Transite Lateral Distribution Pipe Maintenance**

As mentioned previously, the proper means of attaching nozzles to Transite pipes requires the usage of lateral-eared adapters that are securely attached to the pipes with stainless steel worm-gear type hose clamps or stainless-steel banding. It should be noted that the design of the lateral eared adapter varies from one pipe size to the next to match the curvature of the pipe outside diameter. Where Transite pipes have been replaced with fiberglass (RTR) or PVC pipes, the lateral eared adapters should be attached, preferably in the factory, using self-tapping screws and glue. A number of age-related anomalous conditions in Transite lateral distribution piping have been observed with increasing frequency in recent years, including:

- Degradation of the grouted pipe-to-flume connection. The resulting gap (Figure 35) may be sealed with an elastomer coating (Figure 36).
- Degradation of Transite pipe coupling o-rings (Figure 37). Failure of the rubber o-rings requires replacement of the o-rings.
Figure 35: Degraded Grout with Gap between Pipe & Flume

Figure 36: Repair with Elastomer Coating

Figure 37: Degradation of Transite Coupling O-Ring
VI.C. PVC Pipe Extensions and Couplings

PVC extensions to asbestos-cement lateral pipes have been incorporated into the water distribution systems of at least 35 U.S. natural draft cooling towers. Extending the lengths of lateral distribution pipes facilitates creation of additional nozzle positions near the cooling tower perimeter for improved water distribution. A typical PVC pipe extension assembly is shown in Figure 38 below.

![Figure 38: PVC Pipe Extension Assembly](image)

The pipe extension assembly normally includes a section of 6-inch diameter Schedule 40 PVC pipe, PVC end cap, one or more nozzle assemblies (including lateral eared adapters and hose clamps), and, in some cooling towers, an elastomeric pipe coupling with stainless steel hose clamps.

When new, an elastomeric coupling is soft and flexible and can be adapted to the 6-inch diameter feeder Transite pipe fairly easily. Experience has shown, however, that PVC pipe extensions attached to Transite laterals using elastomeric couplings have a tendency to become disconnected, even when the end of the PVC extension is supported by a stainless-steel pipe end hanger. The separation of one or more PVC pipe extensions from their Transite feeder pipes can result in loss of thermal performance efficiency and can damage PVC fill modules and asbestos-cement fill sheet arrays. If a number of PVC pipe extensions are down, the water level in the flumes can drop to levels that impact the performance of the entire water distribution system.

If an elastomeric coupling separates from its Transite feeder pipe, it is oftentimes difficult to reattach because, after a time, the coupling becomes hard, inflexible, and sometimes deformed. A more reliable means of adapting PVC pipe extensions to asbestos-cement laterals is depicted in Figure 39. As shown at right, the PVC pipe is adapted to the Transite pipe by first wrapping strips of ⅛-inch thick neoprene rubber around the end of the PVC pipe until the outside diameter of the PVC pipe matches the outside diameter of the Transite pipe section. The pipe connection can then be secured with a stainless steel universal clamp-type coupling (Figure 40).

![Figure 39: Attachment of PVC Pipe Extension](image)

![Figure 40: Stainless Steel Clamp-Type Coupling](image)
VI.D. Spray Nozzle Designs and Maintenance Requirements

Nozzle designs used in Hamon/Research Cottrell counterflow natural draft cooling towers have evolved considerably over the years, taking advantage of improvements in material technologies and manufacturing processes. The nozzle design used in a few of the first of these cooling towers built in the United States is shown in Figure 41. This nozzle design, which very likely no longer exists in any U.S. cooling tower, features a dish-type splash-plate that produces a hollow-cone spray pattern. Many early-design asbestos-cement-filled counter-flow natural draft cooling towers originally used the so-called “umbrella”-type nozzle (Figure 42). This nozzle design also produces a hollow-cone spray pattern and includes an internal “spider” that supports the splash plate rod. The presence of the internal rod support in the umbrella nozzle, however, makes this nozzle design very susceptible to pluggage with debris, scale, and mud. For this reason, it has been replaced in most operating cooling towers with yoke-type nozzles (Figures 43 and 44).
Two versions of the single-splash-plate yoke nozzle are available. One version was designed in the United States by Research Cottrell (Figure 76) and one version was designed in Belgium by Hamon (Figure 77). Although the geometry of the threads of the two yoke nozzle designs are the same, the bodies of the nozzles are very different and the color-coding and sizes of the nozzle orifice inserts are different. Both yoke nozzles produce hollow-cone spray patterns.

It should be noted that the splash-plates of the American yoke nozzles are no longer attached with nuts and bolts as shown in Figure 76. Today, the splash-plates of both yoke nozzle versions are snapped onto the body of the nozzle. It is very important, when purchasing replacement yoke nozzles, to specify that all four of the splash plate clips be ultrasonically welded to the nozzle body. Otherwise the snapped-on splash-plates may become loose after a few months in service and begin to fall off, requiring replacement of the entire nozzle assembly. It should be noted further that today’s condenser tube cleaning darts can cause the snapped-on splash-plates to break off on impact. Because the hydraulic head versus flow characteristics of the two yoke nozzle designs are different, the nozzles are not directly interchangeable. It is best, therefore, not to mix the two designs in the same cooling tower.

In recent years it has been observed that the yoke nozzle orifice inserts in some U.S. cooling towers have become extremely embrittled, to the extent that the orifice inserts crumble when checked for pluggage. Brittle yoke nozzle orifice inserts should be replaced upon discovery.

Two versions of full-cone spray nozzles, commonly used in counterflow natural draft cooling towers, are also available: 1) the SFF nozzle (Figure 45) and 2) the French Sprayer, also known as the “ATP nozzle” named after the original U.S. manufacturer, American Tower Plastics (Figure 46). The threads of the SFF nozzle and the French Sprayer are different, as are the nozzle orifice insert color-coding schemes, and the hydraulic performance characteristics.

Experience has demonstrated that the French Sprayer has two performance advantages over the SFF nozzle:
1. The means of attachment of the French Sprayer splash-plate is mechanically superior to the means of attachment of the SFF nozzle splash-plate. SFF nozzle splash-plate breakage and separation from the nozzle body occurs frequently, resulting in erosion damage to PVC fill modules and diminished cooling tower thermal performance efficiency.

2. Because the French Sprayer splash-plates have more “teeth” than the splash-plates of the SFF nozzle, the spray pattern of the French Sprayer is superior to that of the SFF nozzle. For these reasons it is recommended that SFF nozzles be replaced with French Sprayers.

VI.E. Water Distribution Flume Access and Maintenance Requirements

Access to the interior of water distribution flumes is essential for inspection of:

- mud and silt accumulations
- flume nozzle pluggage
- the physical condition of flume de-silting valves
- the physical condition of flume joint seals
- the physical condition of pipe-to-flume connections
- the physical condition of flume slide gate rubber seals
- the interior of lateral distribution pipes

With reference to Figure 39, access to the interior of the flumes in early-design Hamon/Research Cottrell natural draft cooling towers can be easily accomplished by lowering a ladder into the standpipe at the end of the flume. Precautions must be taken, however, to ensure that inspectors and maintenance personnel do not fall into the riser pipe.

Access into the interior of water distribution flumes in Hamon/Research Cottrell natural draft cooling towers constructed in the 1970s and 1980s, on the other hand, require the erection of scaffolding in the riser standpipes. A recommended riser pipe scaffold design is shown in Figures 47, 48, and 49.

A number of age-related anomalous conditions in water distribution flumes have been observed with increasing frequency in recent years, including:

- Corrosion of flume vent tubes. The flume vent tubes (Reference Figure 9) in some cooling towers are manufactured from 2.0-inch diameter hot-dipped galvanized steel pipe. Many of these tubes have become badly corroded and are broken or completely missing. Missing flume vent tubes can adversely impact cooling tower thermal performance by allowing hot water, that should be discharged by the nozzles, to spill out onto the flume walkway. Damaged flume vent tubes should be repaired using PVC pipe.
Figure 47: Recommended Riser Scaffold Arrangement for Flume Access

Figure 48: Riser Standpipe Access Ladder

Figure 49: Flume Access Platform
- Degradation of the joint seals between precast concrete flume sections. The effect of missing or blown-out flume joint seals on cooling tower thermal performance can be significant because it allows un-cooled inlet water to be introduced directly into the cold water basin. One reliable means of repairing flume joint seals involves fastening standard 9-inch wide water-stop material (that features a central bulb) to the inside of the flume joint, utilizing stainless steel compression plates that are anchored to the concrete surfaces (Figures 50 and 51). To ensure a water-tight seal, mastic should be applied to the water-stop material.
VII. DRIFT ELIMINATOR MAINTENANCE

Today, the asbestos-cement drift eliminators in many cooling towers have been damaged in varying degrees by foot traffic. Accordingly, broken drift eliminator blades are most often seen in areas immediately adjacent to flume walkways. Because minor drift eliminator breakage does not adversely impact cooling tower thermal performance or drift emissions, cosmetic repairs are rarely implemented. However, where entire 8-bladed drift eliminator panels have been severely damaged, drift eliminator repairs and restorations may be completed using light-weight cellular-type PVC drift eliminator panels. The PVC drift eliminator panels may be placed directly on top of Transite lateral water distribution piping. However, if Transite piping has been replaced with PVC or fiberglass piping, it is usually necessary to install square pultruded FRP tubes on top of existing precast concrete pipe support beams to facilitate adequate support of the PVC drift eliminator panels.

Some cooling tower owners have taken permanent precautionary measures to protect asbestos-cement drift eliminators from damage in high traffic areas. Figure 52, for example, shows protective fiberglass grating that has been placed over asbestos-cement drift eliminators near an access hatch where a ladder is provided to permit access to the top of fill elevation.

![Figure 52: Fiberglass Grating Used to Protect Drift Eliminators](image_url)
Figures 53 and 54 show permanent platforms constructed of stainless steel grating that extend out over the asbestos-cement drift eliminators in order to increase the size of the available work areas adjacent to the cooling tower entry door and around a riser standpipe, respectively.

Figure 53: Stainless Steel Platform over Drift Eliminators at Cooling Tower Entrance Door

Figure 54: Stainless Steel Platform over Drift Eliminators at Cooling Tower Riser Standpipe
VIII. TRENDS IN COUNTERFLOW NATURAL DRAFT COOLING TOWER RENOVATION

Maintenance of America’s decades-old asbestos-cement-filled counterflow natural draft cooling towers has necessitated replacement, in part or in whole, the asbestos-containing components with new PVC or fiberglass components. It is of interest to note that the oldest 1960’s vintage Belgian-designed counterflow hyperbolic cooling towers in the United States (at the Keystone Generating Station near Shelota, Pennsylvania) were recently completely renovated utilizing state-of-the-art anti-fouling non-contact sheet film-type PVC fill modules and high efficiency, low pressure drop cellular-type PVC drift eliminator panels, all bottom supported on new pultruded composite fiberglass-reinforced polyester beams. The water distribution systems of these 52-year old cooling towers were renovated with PVC lateral water distribution piping and state-of-the-art high performance, full-cone spray nozzles.

Infusion of new cooling tower technologies into aging natural draft cooling towers, that were originally designed with asbestos-cement internals, can provide assurance of extended, reliable water cooling service and, if strategically implemented, can provide a level of cooling tower thermal performance efficiency that exceeds that of the original design.
IX. REFERENCES

