CTI Journal
The Official Publication of the Cooling Technology Institute

COOLING TECHNOLOGY INSTITUTE
Est. 1950

www.cti.org

www.cti.org - log on

Winter 2011
Volume 32, No. 1
Are you still doing this...

And ending up with this?

Call on the Screening Experts

Replace your existing bar screens on line, without any basin modifications with our unique, continuous screening

Vari-Flow SS Series

Traveling Sump Screen

The Vari-Flow SS Series Traveling Sump Screen is custom fabricated to easily replace stationary screens while your unit stays in full operation. The screens can be automated and are available in more than 20 different screen mesh sizes. The Traveling Sump Screen is patented, manufactured and distributed by Industrial Cooling Tower Services. Let the experts handle your equipment screening needs with this easy-to-use, cost efficient solution.

Industrial Cooling Tower Services, Incorporated

(225) 261-3180 • www.ictsinc.com
Contents

Feature Articles
8 Physical Water Treatment Utilized in Food Manufacturing and Distribution Generation  
David McLachlan
22 Fire Resistant Wall Systems For Water Cooling Tower Systems  
Mike Bickerstaff
44 What Is The Best Water Treatment Program For My Tower  
Robert J. Cunningham
68 Complex Structural Analysis Simplifies Repair Phasing in Restoration of Hyperbolic Cooling Towers  
Narendra Gosain, Farouk Mahama, Ph.D.
84 Copper Corrosion Control And Minimized Copper Discharge From Cooling Tower  
Jasbir S. Gill, Ph.D. and Ed Grodecki

Special Sections
91 CTI Licensed Testing Agencies
92 CTI Certified Towers
98 CTI ToolKit

Departments
2 Multi Agency Press Release
2 Meeting Calendar
4 View From the Tower
6 Editor’s Corner
7 2011 CTI Table Top Information
For Immediate Release
Contact: Chairman, CTI Multi-Agency Testing Committee
Houston, January 3, 2011

The Cooling Technology Institute announces its annual invitation for interested drift testing agencies to apply for potential Licensing as CTI Drift Testing Agencies. CTI provides an independent third party drift testing program to service the industry. Interested agencies are required to declare their interest by March 1, 2011, at the CTI address listed.
Swifter CTX Series

The next generation of industrial fans for cooling towers and heat exchangers.

swifterfans.com

GLOCON INC • PARSIPPANY NJ USA • 973-463-7300

Swifter
This year has been a very active one for CTI! This year marks CTI’s 60th anniversary, and the organization continues to grow worldwide as the leader of cooling technology.

As evidence, an agreement between CTI and Eurovent was recently approved and signed by both parties. Eurovent is the European Committee of Air Handling and Refrigerant Equipment Manufacturers. Eurovent is very active providing product certifications for other products based on third party testing. They provide product certifications for 180 manufacturers in 18 programs. Our agreement with Eurovent will provide identical standards for cooling tower certification throughout the world and will greatly expand CTI’s recognition in Europe, the Middle East, Africa and India.

In other happenings, the newly chartered website committee is preparing a new look for our website to help new and frequent visitors alike navigate our site with greater ease. Our goal is to create an uncluttered, professional home page with navigation bars on one side that allows users to click through to the desired content quickly and intuitively. A new area will be devoted to members only, where members can access working task groups’ drafts of codes & standards, the membership directory and Owner/Operator Council information. A search feature will be added to help retrieve that CTI technical paper you need to reference as well as find the proper code or standard for your project. Visit our current website for updates as to our progress.

The Long Range Planning Committee, with assistance from the R&D committee, has been very active in developing a test plan and cost proposal to investigate alternate pitot tube designs to replace the present standard “Simplex” pitot tube design. The Simplex design has been found to have measurement inaccuracies under certain flow conditions and installations, so this study will be of great interest and benefit to the cooling technologies industry.

The CTI Thermal Certification program has been a great success and continues to grow worldwide. CTI has certificated 66 models of cooling towers and presently has 26 companies participating in the program. Approximately 40% of the participating companies are located outside the USA. Due to this worldwide success and growth, CTI is now evaluating our organizational structure to determine what changes are necessary to support this worldwide interest and to see what assets are needed to further develop other product certifications. The Thermal Certification Continuation Committee will be presenting a draft business plan to the CTI Board of Directors at the February 2011 meeting.

Speaking of February 2011, I certainly look forward to seeing each of you at our 2011 Annual Conference in San Antonio, Texas. The conference is being held at the Westin River Walk Hotel from February 6-10. The program committee has a full slate of technical papers that will be of great interest to cooling system owners and users. Informative panel discussions and educational seminars will be presented giving attendees the latest in cooling technology development. The table top display by manufacturers has been a big success and CTI has reservations from all major suppliers to exhibit their products at the conference. Please be sure to attend our annual conference in San Antonio and do not hesitate to become involved.

CTI has instigated an “Ambassador Program” to assist new attendees to the conference. Please be sure to attend our annual conference in San Antonio and do not hesitate to become involved. CTI has instigated an “Ambassador Program” to assist new attendees to the conference – Look for the Ambassador Badge on the members name tag and ask their assistance. They will be your personal guide to getting the most value from all CTI has to offer.

As always, I wish to thank the dedicated CTI staff and multitude of members who volunteer their valuable time and expertise in making CTI a world class technical organization and for making my first year as President a good one.
PUSHING THE BOUNDARIES OF FAN PERFORMANCE

HOWDEN COOLING FANS, ACKNOWLEDGED FOR THEIR INNOVATIVE LOW NOISE DESIGN AND RELIABILITY, NOW OFFER UNPRECEDENTED ENERGY SAVINGS AS WELL.

Redesigned blade profiles optimise the efficiency of the system and provide measurably better performance and lower power consumption.

Easily the most efficient Howden cooling fans ever designed, the D-Series and K-Series keep Howden at the leading edge of cooling fan technology.

For more information contact:

Howden Cooling Fans
E-mail: cooling.fans@howden.nl
Visit us at: www.howdencoolingfans.com
Dear CTI Journal Reader,

Another year rolls by, finding CTI continuing to organize and position for the challenges ahead.

We, as an industry, have weathered difficult financial times in relatively good health. The look ahead remains somewhat uncertain, but hopeful. The CTI organization, under the capable leadership of its President, Jess Seawell, has worked diligently to plan for the future needs of the organization. A new program is in process to begin certification of the performance of tower components per CTI standards. An example in consideration is the performance rating of firewall designs for cooling tower applications. Also, a cooperative thermal certification agreement with the Eurovent Certification Company has been signed and the program launched in 2010 to bring thermal certification to Europe with a European program leveraging the CTI certification program. Exciting changes for CTI, indeed.

A number of proposals for organizational changes are expected to come before the organization leadership at the upcoming Annual Meeting in San Antonio, in large part to accommodate the needs for management of the new programs mentioned above. Members are encouraged to attend the meeting in February.

CTI needs your participation in the code and standards development process. Many significant new documents and significant modifications to existing ones are in process. One needs to attend and participate in the open committee meetings to be on top of what is coming for the future in our industry.

Plan to attend the Annual Meeting in February, in San Antonio, and the Committee Workshop at Amelia Island, Florida in July.

We look forward to seeing you there.

Respectfully,

Paul Lindahl, CTI Journal Editor
Physical Water Treatment Utilized in Food Manufacturing and Distribution Generation

By David McLachlan
Fluid Treatment Solutions, Inc.
ElectroStatic Technologies Inc.

Abstract:
A technical review of the fundamentals of high voltage PWT (Physical Water Treatment) systems will be presented. The thermodynamics and surface phenomena associated with the water chemistry in scale formation will be delineated. Address the connection between the scientific hypothesis and field results found in the food industries. These cooling towers will cover a wide range of locations (AZ, KS, and FL) and their feed water chemistry.

Background:
Physical Water Treatment (PWT) refers to systems that treat hard water for scale prevention in re-circulation heat exchange equipment without the addition of chemicals. Physical water treatment is sometimes referred to as non-chemical devices (NCD), physical water conditioning (PWC), etc. The observations suggest that the majority of PWT devices work by promoting bulk precipitation of calcium carbonate out of solution so it is not available to form scale on surfaces, [1-4]. This process produces colloidal particles that provide an enormous surface area for preferential growth of remaining minerals in solutions. These mechanisms will be discussed from a scientific standpoint with a focus on thermodynamic and heterogeneous catalysis via surfaces and supported by field results.

Magnetic fields effects were the first PWT’s to be considered by developers and dominated early PWT’s. A permanent magnet device was granted a German patent in 1890, followed by magnetic PWT’s spreading throughout the world, with notable success in Europe and Soviet Union. Permanent magnets gained in performance as stronger strength magnet became available in the 1960 and innovative designs allowed for internal multi-pole magnetic to be introduced. Electrostatic PWT’s followed with a US patent granted in 1957 for a device generating a constant 3 KVdc, and has evolved over time to over 35KVdc, and is available in different shapes to address various applications. In 1990, induction coil technology was introduced to the US and has generated a strong interest in the market place.

The driving force in the marketplace was initially the control of scale, followed by reduced operating costs, environmental impact and safety. New technology can develop via trial and error or through the use of the scientific method, a more systematic approach. In the following approach observations are made and information recorded. The goal is to find a pattern or sense of order in observations and understand the origin of this order. This method can lead us to a tentative explanation or hypothesis that guides in the development of the technology and as additional data is gathered, modification of the hypothesis takes place continually refining the theory.

The early PWT’s inconsistencies were in part due to misguided designs and/or applications. At the start, a lack of understanding of the fundamentals behind the PWT process may have led to some of these inconsistencies. Using the developing hypothesis based on scientific and field data has allowed for an improvement in the designs and applications, leading to enhanced performance. To move the design and application of PWT devices forward, an understanding of the mechanism(s) and scaling fundamentals needs to be utilized. Again, bulk precipitation proposed by Cho [8], which impacts a number of the chemical and physical variables of these PWT’s. As these technologies improve other factors emerge such as variation in flow, dirt load, and lax maintenance. These later operational concerns sometimes direct the market focus to a more inclusive service based and performance orientated offering for the small to medium tower users.

The majority of the reference sites will in general lead one to conclude that PWT’s are not water-softening devices since it does not remove minerals from the water. In addition it can be stated that PWT’s do not change the structure of the water molecules. Therefore, if the effects of PWT devices are directed at the scaling problems associated with the heat exchange surfaces one should focus on the performance of heat exchanger and the scaling mechanism at those surfaces.

Temperature, concentration, pressure, and pH are all factors in determining the amount of solute (minerals) that can be dissolved by the solvent (water) to produce a saturated solution. Salts such as CaCO₃, CaSO₄, and MgSiO₃ have inverse solubility, i.e., as the temperature increases these minerals have lower solubility. This can result in crystallization fouling in and around heat exchanger [5-7] surfaces. In this technical review the parameters of time (reaction time), active surface sites and driving force (degree of saturation / thermodynamics) coupled with the impact of an electrical field plays in the seed crystal formation and growth. These factors may be parallel and are not necessary mutually exclusive. These various parameters aid in understanding the physical and chemical paths that may be taken in achieving the mechanism that allow PWT’s to move ions in solutions to particles in suspension.

Since, the main emphasis of this paper will be on calcium carbonate scaling; a brief discussion on crystallization and particulate fouling is warranted. Crystallization fouling (hard scale) is a form of heterogeneous nucleation and growth of calcium carbonate on pre-existing surfaces. Textbooks on precipitation and solidification maintain that the true crystal growth process is primarily the result of single atoms / ions arriving at or departing the solid surface. This process allows for crystal growth that can be defect free, hard and tightly adherent to the surface.

Particulate fouling is a deposition process of particles (corrosion products, bacteria, etc.), including small carbonate crystals (col-
Structured Packings for Cooling Towers

As the pioneer of plastic components for cooling tower applications we help our customers to meet their requirements!

Through constant product development and optimization we offer many different fill media structures and surfaces that allow the adaptation of the fill to the specific water quality in the cooling circuit and thus optimizing the selection.

Most of our products can be produced in both PP and PVC. With our patented manufacturing processes we offer reinforcement of the leading edges as well as a uniform material thickness across the surface.

- Cross-fluted film fills for high cooling capacity
- Vertical flow fills for high fouling applications
- Anti-legionella film fills prevents growth of bacteria
- Splash / Trickle fills for poor water qualities

Our Standard – Thermal welded film fills!
There are just as many weld points in our packs as there are glue points in glued packs. High-quality GEA 2H packings are produced today at a variety of locations around the world!

Today's innovation is tomorrow's standard!

Thermal Engineering

GEA 2H Water Technologies GmbH
Dieselweg 5 · 48493 Wettringen · Germany
Telephone +49 25 57 / 93 90-0 · Telefax +49 25 57 / 93 90-49
www.gea-2h.com · info.2h.de@geagroup.com

US Office: 14151 Interdrive West · Houston, Texas · 77032
Telephone 281.227.7900 · Fax 281.227.7084
www.gea-2h.com · info.2h.us@geagroup.com
In practice, water chemistry is complex; therefore, one would expect that the PWT underlining explanation of the mechanisms that prevent scaling would also be complex and must draws on many fields such as surface chemistry, kinetics, thermodynamics, physics, etc. No underlying, unified hypotheses exist but several alternatives can be put forth. These alternatives theory are not necessarily mutually exclusive and are supported by various set of conditions and observations. However, the fundamentals should be applied, remembering that the underlying principals that control chemical equilibrium reactions much be addressed. The main considerations utilized here are: activation energy, collision rate theory, and thermodynamics, all of which can have a time (rate) component.

The primary parameters that affect these considerations and their impact on scaling are: temperature, pressure changes, reactant concentration (including pH), surface catalysis, and electrical interaction. There is a large quantity of significant but empirical facts intermixed with useful theories with the basic one stated above.

Electrical Properties of Water

Pure water is an excellent insulator, but its conductivity increases significantly with the addition of small amount of ionic material (in solution), such as mineral salts or carbon dioxide. Water can then be readily electrolyzed into oxygen and hydrogen gases, where in the absence of dissolved mineral ions this is a very slow process, as very little current is conducted as these ions are the primary current carriers. Water can be split into hydrogen and oxygen, by passing an electric current through it, a process called electrolysis. At a low electrical potential of only several volts, the H⁺ and OH⁻ ions in the water migrate toward the cathode and anode, respectively.

The water molecule has an asymmetrical shape, with the hydrogen atoms sitting like two ears on the larger oxygen atom, with the ears charged positively and the oxygen end being negatively. This dipole gives water the characteristics of being know as “The Universal Solvent”. Water is a good solvent due to this polarity. When a mineral (like a salt) goes into solution in water as an ion, it is surrounded by water molecules (Hydration). The negative dipole ends of the water are attracted to the positively charged ions and the positive dipole ends attracted to the negative ions. These hydration clouds surround the ions isolating them from each other keeping them in solution.

Due to this high degree of polarity, water has a large dielectric constant of 80. This large dielectric constant is indicative of the alignment of the dipolar water molecules aligning up with an applied electrical field. Water’s dipolar nature can be demonstrated by holding an electrically charged object near a small stream of water causing the stream to be attracted towards the charged object. These characteristics; dipolar molecules, hydration, and dielectric constant play an important role in PWT’s water chemistry.

Seeding and Supersaturation

The hypothesis put forth for PWT is bulk precipitation, which prevent scaling by means of particulate fouling. The ability of small particles to act as nucleation sites for growth of calcium carbonate crystals has been sited and reported by Troup and Richardson (11). They reported that suspended solid matter, even dust particles in a supersaturated solution could induce nucleation in water. “Seeding”, a concept of adding solid particles for the prevention of scale in heat exchanger operations is thought of as a mechanical method of scale prevention as opposed to chemical treatment. Badger, [12]
New!

DTEA II™ Slow Release Tablets
Cooling Water Solution in a Tablet

Takes 10 Minutes & Lasts for 2-4 Weeks!
DTEA II™ SR and DTEA II™ SR Plus SC tablets are slow-release solid formulations of DTEA II™

- Organic Deposit & Corrosion Control
- Specific Use: Small to Medium Sized Cooling Towers
- Type 1 - DTEA II™ alone
- Type 2 - DTEA II™ with added corrosion & scale inhibitors
- Depending on tablet, 1 dose lasts 2-4 weeks

The DTEA II™ slow release tablets are two new forms of the well known DTEA II™. It is a dispersant, organic deposit control & removal agent, and corrosion inhibitor.

Product Features & Benefits
Unique Slow Release Formulation Benefits
- Slowly dissolves in water
- No feeding equipment necessary
- Reduce service call visits
- Designed for systems with:
  - Minimal monitoring
  - High biocide demand
  - High recycle
  - High pH
  - High solids

New!

AMSALite™ IV
A Truly Affordable ATP Luminometer!

ATP is a tried and true method for testing surface and bulk water microbial activity and fouling rates. Easy to use and simple to read, the AMSALite™ IV produces results in just 30 seconds using 3M™ Clean-Trace™ Water ATP test devices.

- Superior reproducibility from low to high counts
- Direct Photon Counter Technology*
- Compact hand-held design
- Works with 3M™ test pens or other popular brand
- Takes readings in battery or AC mode
- Equivalent to 3M™ NG

* Direct photon counting is superior to low cost photodiode units

AMS, Inc.™
1406 E. Pine St. • Midland, MI 48640
Tel: (989) 639-0377 Fax: (989) 639-4440
Email: sales@amsainc.com
www.amsainc.com

AMS, Inc.™ manufactures DTEA II™ chemicals and ATP instruments. AMS, Inc.™ exclusively serves the water treatment service professional and is a 3M™ Microbiology products distributor.
and Charuit [13] reported that hard scale could be reduced by simply feeding fine CaCO₃ or CaSO₄ particles in industrial heat exchanger. The degree of supersaturation, departure from equilibrium or driving force also can play a significant role in the formation of adherent (hard) or non-adherent (soft). Adherent scale relates to crystallization fouling where-as non-adherent relates to particulate fouling. Cowan and Weintritt [14,15] reported that calcium sulfate, calcium carbonate, and barium sulfate all precipitated at high degree of supersaturation forming non-adherent small crystals, but at low degree of supersaturation formed adherent large crystals on heat transfer surface. Cowan and Weintritt also reported that seeds of the same composition as the scaling-forming composition resulted in optimum precipitation conditions. Tijing, et al., [16] reported that for hard water with an electrical conductivity of 2300-2700µS/cm that was circulated at room temperature continuously for 66 hr the total number of particles in the water for the PWT cases increased by 165-540% as compared with those for the no-treatment cases (non-PWT).

The seeding and supersaturation experiments support what is happening with the use of PWT’s. As postulated earlier, PWT produces small seed crystals in water in the form of very fine calcium carbonate particles prior to the water entering a high temperature zone, where the solubility decreases. Calcium carbonate adheres to the surface of these fine particles growing them in size. These larger particles tend to form soft-sludge which can be removed by the shear force produced by flow velocity, [8, 10].

**Thermodynamics of CaCO₃ Precipitation**

One can approach thermodynamics from different vantage points; the chemical reactions and/or nucleation. The latter can be homogeneous or heterogeneous in which thermodynamics (Gibbs free energy) comes into play. Gibbs energy of nucleation is the summation of two factors, a bulk energy term and a surface energy term.

\[ \Delta G (nucleation) = \Delta G (bulk) + \Delta G (surface) \]

Note that \( \Delta G (bulk) \) is always negative and driven in part by the degree of supersaturation while \( \Delta G (surface) \) is always positive and contains an interfacial tension consideration. Most nucleation processes are physical or geometrical in nature, but electrical and chemical factors can be active, (see discussion on catalytic reactions). When a critical radius size embryo is reached, aided by a substrate, at the point where \( \Delta G (bulk) \) \( \geq \Delta G (surface) \), a stable surface (liquid / precipitate) can form and crystal growth can continue. Hence, a foreign material (substrate), which reduces the interfacial tension between the solid and liquid phase, will enhance the nucleation rate.

To further promote nucleation the factors of concentration and activation energy can be address via the applied electrical fields. The electric field induces diffusion of ions (as in electrolysis) and hereby can result in localized concentration gradients plus the applied electric potential will distort the hydration sheath increasing the number and success of the collisions between ions that can induce nucleation.

From the chemical reaction approach the reaction of interest is:

\[
\text{Ca}^{++} + 2\text{HCO}_3^- \rightarrow \text{CaCO}_3 + \text{CO}_2 \text{(gas)} + \text{H}_2\text{O} \text{ (basic)} \tag{Eq.1}
\]

Precipitation (CaCO3) and dissociation reactions are more complicated as shown by Cho [10]. The dissociation of bicarbonate ions into the hydroxide ions and carbon dioxide (in aqueous solution) is shown in:

\[
\text{HCO}_3^- \leftrightarrow \text{OH}^- + \text{CO}_2 \tag{Eq.2}
\]

The CO₂ escapes increasing the hydroxide ions, OH⁻, concentration resulting in an increase in pH (basic). In cooling towers the pH normally increases since the water is heated plus [fill, spray, etc] passes through the air to enhance evaporation i.e., releasing CO₂. The next chemical step is the hydroxide ions produced from Equation 2 combines with existing bicarbonate ions, producing carbonate ions and water:

\[
\text{OH}^- + \text{HCO}_3^- \leftrightarrow \text{CO}_3^{2-} + \text{H}_2\text{O} \tag{Eq.3}
\]

The final step is for the carbonate ions, CO₃²⁻, to react with the calcium ions resulting in the precipitation and crystallization of calcium carbonate.

\[
\text{Ca}^{++} + \text{CO}_3^{2-} \rightarrow \text{CaCO}_3 \tag{Eq.4}
\]

With these three chemical reactions forming the steps for calcium carbonate precipitation, Dr. Cho [10] explored several possible methods by which PWT can affect this process. One method considered was a direct effect of PWT on the reaction rate, i.e., equation 2 & 3. Calculations indicate the energy for the rate limiting reaction to be in the eV range which is larger than the PWT’s sited above can directly apply by itself and other alternative path need to be explored, (see discussion below on surface irregularities).

An alternative process [18] that could be active in addition to the reactions stated above and one that utilizes calcium hydroxide converting CO₂ and HCO₃⁻ to CO₃²⁻ causing CaCO₃ to precipitate, as follows:

\[
\text{HCO}_3^- \leftrightarrow \text{CO}_3^{2-} + \text{H}^+ \tag{Eq.5}
\]

While in the pH range of 8.2 and 9.6, the carbonate ions and the bicarbonate co-exist, (see Fig. 4.4 of [18]) or

\[
\text{Ca(OH)}_2 + 2\text{CO}_2 \rightarrow \text{Ca(HCO}_3)_2 \tag{Eq.6}
\]

\[
\text{Ca(OH)}_2 + \text{Ca(HCO}_3)_2 \leftrightarrow 2\text{CaCO}_3 + 2\text{H}_2\text{O} \tag{Eq.7}
\]

This process utilizes the elevated pH, (hydroxide ion), which illustrates the complexity and the variables in the precipitation process. However, going back to equation 2, let examine its possibilities in a PWT environment.

**Surfaces and Heterogeneous Catalysis**

In conjunction with the thermodynamic and electric fields, heterogeneous catalytic was explored [10] and its effect at surfaces. The catalysis, in this case, a solid, provides a surface on which the...
Water Additive Technologies

engineered for the extreme

BWA leads in the discovery, development and global supply of innovative specialty chemical technologies for the Industrial, Oilfield and Desalination markets. BWA leads the market segments it serves in over 80 countries.

BWA products protect water systems, ensuring operating efficiency and asset longevity. They perform well in EXTREME conditions in desalination, cooling & boiler water, oilfield, and other process water applications.

BWA has a strong commercial and technical team, with an average of 15 years water treatment industry experience and strong education backgrounds in chemistry or chemical engineering.

With our product innovation, global capability and strong workforce, BWA strives to be our service company customers’ most valuable technology resource.

Please contact cti@wateradditives.com with questions or visit www.wateradditives.com.

Clear solutions for water treatment™
The average electric field produced by PWT devices can be increased

\[ E_o \sim \frac{q}{R^2} \]  

Eq. 5

curvature squared of the surface:
be formulated as the charge of a particle divided by its radius or
be incorporated, but not consumed during the bulk precipitation
by the reaction.  In aqueous solutions, dirt or mineral particles could
process using PWT.

Returning to the energy required to affect equation 2, which will
be compared with the energy that is attainable on a small scale as a
result of electrostatic effects of surface irregularities (similar to the
heterogeneous electrocatalysis).  In heterogeneous catalytic reactions
the rate can be increased without the catalysis being consumed
by the reaction.  In aqueous solutions, dirt or mineral particles could
be incorporated, but not consumed during the bulk precipitation
process using PWT.

In reviewing this approach, ions are first diffused from the bulk
water to irregularities on a surface.  The size of the local irregulari-
ties and the enhanced electric field around these irregularities are
explained as follows [20].  The average electric field produced by
an electrostatic interaction with charged particles at a surface can be
formulated as the charge of a particle divided by its radius or
curvature squared of the surface:

\[ E_o \sim \frac{q}{R^2} \]  

Eq. 5

If an extremely small irregularity of radius r, the local electric field
(EL) produced would be:

\[ E_L \sim \frac{q}{Rr} \]

Irregularities on a surfaces or a particle tend to enhance the electric
field \( E_L \rightarrow E_o \), plus any natural surface charge (due to free radicals)
and results in a larger field within the volume of the irregularities.
The average electric field produced by PWT devices can be increased
significantly in the area of the irregularities depending on their size.
This coupled with the diffusion of ions, as in electrolysis, these lo-
cal irregularities can produce a strong enough electrostatic effect
to induce the rate-limiting reaction (Eq. 2), e.g., acting as charge
centers, accelerating the dissociation process of bicarbonate ions.
As the concentration of \( OH^- \) ions increases at these areas, carbonate
ions are formed (Eq. 3) which allows the precipitation of calcium
carbonate (Eq. 4).  Note that this is coupled with the increase in
pH, the increase in concentration, and supported by heat energy
(temperature).  These latter two are discussed below.

**Concentration and Temperature Distribution**

In the chemical reaction to form a compound, the two or more mol-
ecules, ions, etc. must come into contact with each other (collide)
and then they may react.  Hence, all collisions of reactants (ions or
molecules) do not form compounds and they bounce off each other
and wait to try again.

The probability that a reaction will take place is a function of concen-
tration, the energy of the collision (kinetic energy), as well as correct
orientation of the reactants.  Concentration can vary from region to
region within a liquid due to turbulent, diffusion, etc. resulting in
temporary localize variations in concentration (distribution).  Note
that an applied electrical field can cause ion directed movement,
as in electrolysis, resulting in additional concentration variations.

The available kinetic energy to supply the necessary activation
energy (collision) can be obtained from a combination of heat (vibrations,
turbulence, pressure changes, and/or electrical fields.  As applied to
chemical reaction, temperature is the best understood variable.  At a
given temperature the heat energy will vary over a wide range, from zero
to very high values, with the most number of particles averaging at the nominal value for that temperature.  As the temperature increases, the available energy and the number of collisions increases.  At elevated temperature the reaction rate of most reactions, in our case precipitation of CaCO3 on the heat
exchange surfaces increases.  However, one should note, that even
at lower temperature reactions can take place, but at a lower rate.

**Design and Installation Criteria for Electrostatic Devices**

The applied constant value voltage to the positive electrode has
evolved over the years from 3kV thru 10kV and now to over 30kV,
resulting in a higher electrical fields and larger forces on the ions
in solution.

In conjunction with the increased electric field strength, the place-
ment and shape of the electrodes have also evolved.  This evolution
was directed at increasing the size and changing the shape (tubes vs.
plates) of the electrodes.  These later developments have resulted in
improving the uniformity of the high electric field and increasing
the dwell time [the time factor] of the water and ions in the PWT’s
active regions.  Initially tubular electrodes were used and placed in
a grounded (negative) chamber or pipe and in some cases just sus-
pended in the water.  Presently, the tubular electrode is completely
submersible and is surrounded by a grounded metal (negative) cage
so that multiple electrodes (increased treatment volume / dwell
time) can be placed directly into an operating cooling tower thereby
eliminating the cutting of pipes (lower cost).

Fluid Treatment Solutions, Inc., developed a flat plate electrode with
a grounded metal cage, (patent pending), which gives improved
At HUDSON, we understand there is more to the design and production of fan blades than patented technology. We understand that there is more than establishing the highest standards in a manufacturing process, and we understand that there is more than providing the highest quality products and services to our clients – we understand that Hudson has a history.

A history developed over many years of producing the finest fan blades in the industry. We once again raise the standard with the introduction of the latest member of our famous Tuf-Lite® lineage.

**Tuf-Lite III**

- HUDSON's Highest efficiency blade to date
- Developed from the most severe strength testing program to date
- One piece FRP construction
- Leading and trailing edge protection
- Superior “UV” protection
- Individually balanced, interchangeable blades
- Installs in current Hudson hub design
- Size ranges from 11 ft. to 14 ft. and 20 ft. to 10 meters in diameter

With a history of fan blade production since 1955, Hudson continues to push the limits of axial flow fan technology.

For more information on this or any other product, please contact:

HUDSON PRODUCTS CORPORATION
1307 Soldiers Field Drive, Sugar Land, Texas 77479-4072
Post Office Box 20029, Sugar Land, Texas 77496-0029
Phone: (281) 275-8300
Fax: (281) 275-8388
1-800-634-9160 (24 Hours)
E-Mail: hudsonproducts@hudsonproducts.com

HUDSON Products Corporation
A Subsidiary of Hudson Products Holdings, Inc.

www.hudsonproducts.com
electric field uniformity with a larger treatment zone. These submersible electrodes with respective grounded metal cages can be dropped into a cooling tower basin to treat the fluid stream using multiple cages/electrodes creating very large treatment volumes with uniform electric fields [increasing dwell time in the electric field]. By changing from an ‘in-line’ or ‘side-stream’ to a ‘drop-in’ that can treat a large percentage of the water on each pass, improved performance with lower installation cost and down time results.

With the submersible electrodes (positive) and its ground cage (negative), multiple units can be installed in various configurations to meet the space restriction and flow requirements of a cooling tower. For any cooling tower, the flow rate [gpm], the total volume of the system, (to determine the recirculation rate), is taken into account in determining the size and number of the electrodes to be used in treating the system. These considerations allow for a large treatment volume resulting in high dwell time in the treatment zone (improves probability of colloidal formation / suspended particles).

**Field Observation**
(names of clients withheld at their request, call author if contact is desired)

**Food Distribution Center – FL**

A new food distribution center in Florida installed a high voltage electric field PWT system into four 675 ton evaporative condensers manufactured by IMECO / Frick (a total of 2700 tons). Installation took place in the spring of 2007. After a pacification period, the controller for the system was set at 3400 µS. One 1036 electrode and three 1632 electrodes, set at 35kvdc, each in a stainless steel grounded cage were installed at the drain of each tower (see Fig 2). Air born dirt has been an on-going problem with these tower but the tubes have remained scale free through out two seasons.

**Automated Bakery – KS**

This twin Marley cooling tower is rated at 800 tons is over10 years old. The constant voltage PWT system was installed in the fall of 2007 utilizing four 2036 electrodes and eight 1224 electrodes with stainless steel cages surrounding each of two of the sump drains. Cameras are not allowed on site and tight control on information was requested. The cooling capacity of this cooling tower services compressor, process and space requirements of the facility. The feed water has a pH of ~8.4 with a conductivity of ~720µS with a range of the operating recirculating water for pH at 9.0 to 9.3 and a conductivity of between 3000 to 3400µS. These towers operate at COC of ~4.1, (see chemical analysis tables). At the start of the PWT treatment; dirty, foamy water was found in the sump, however, after several months of no chemical additives the water was foam free and clear, however very fine, fluffy dirt settles in the low flow area of the bottom of the tower. A cleaning service once or twice a year was proposed. All heat exchange surface are operating in a stable and satisfactory condition after two seasons of operation per maintenance personnel.
Infinite Possibilities, Definite Solutions

KEMROCK Industries and Exports Limited
FRP Composite Cooling Tower Products

Pultruded Structural Profiles

FRP Headers
FRP Decking Systems
FRP Fan Stack
FRP Stairway
Safety Ladder
FRP Gratings
FRP Cladding

Asoj, Vadodara - Hola! Express Way,
Vadodara - 391 510, Gujarat, INDIA
P +91-2668-666200 | F +91-2668-666400
E ci.sales@kemrock.com
www.kemrock.com
Regional Food Distribution – AZ

Twin cell - EVAPCO evaporative condensers with a 1200 ton total capacity were installed over 20 years ago. One unit was replaced last year and the second unit is scheduled for replacement shortly. The twelve 1224 electrodes were installed in the fall of 2005 (see fig. 4). The condenser tubes are free of scale as indicated by visual inspection (see fig. 5). The operating ranges for the feed water are; pH ~8.2 with a conductivity of 1093µS and the recirculating water at a pH of ~9.0 with a conductivity of 4500µS. (see chemical analysis tables). The average COC is about 4.1. No chemical additives are used during this time.

The central hypothesis (Cho) of PWT’s is bulk precipitation of calcium carbonate colloidal particles which act as nucleation sites for additional growth in the heat exchange system. Heterogeneous catalytic reactions, aided by an electrical field, are proposed as a means to bulk precipitation. These factors, as well as, the degree of supersaturation, temperature, and pH play a role in the successful performance of a PWT and support the central hypothesis. However, the heat exchange system must have the ability to remove the soft sludge via the shear force created by a sufficient flow rate. If the flow rate is too low the soft sludge can settle out and eventually may become hardened with time (ripping).

Laine’s [21] comprehensive review for of non-chemical devices, listed numerous supporting reference as well as sited several third party reviews [3, 22-25].

The degree which these PWT’s perform, e.g., level of COC, their ability to treat given volume and flow rate of water, etc., depends on the strength of the electrical field and the total dwell time that water spends in the active zone. This latter consideration stems from the probability of a chemical reaction occurring, making time an important, but controlling factor.

There are many factors that are driving enhanced interest in PWT systems for standard water treatment applications. Some of these factors are: environmental concerns, the need for water conservation, rising operating costs and concern for employees. The benefit of all PWT’s is the reduction or elimination of chemical additives for the purpose of treating cooling towers. Examine the history of successful installations, the performance criteria, and the likelihood (guarantee) that the supplier and user can reach these goals if both parties live up to good cooling tower practices.

As has been pointed out, the underlying technology behind PWT systems is generally well understood, but perhaps not well accepted, particularly for some applications. It would appear, based on empirical evidence, that the use of these technologies has merit.

Summation

High voltage electrostatic PWT used to treat hard water for scale prevention minimizing the addition of chemicals has scientific and field data support. These systems are used to prevent scaling so that heat exchangers can operate without performance robbing scale.

References

4. Parsons, S. A. (1999). Overview of Recent Magnetic Treatment Research at Cranfield University, MAG3, Anti-scale magnetic Treatment and Physical Conditions, Cranfield University, UK.
Durability, Strength, Performance and Quality


The new Baldor RPM AC\textsuperscript{®} Cooling Tower Direct Drive Motor sets a new standard in cooling tower motors. Designed exclusively for cooling tower applications, the RPM AC motor mounts directly to the cooling tower fan, eliminating high-maintenance gearboxes, drive shafts and couplings. Combined with Baldor's VS1CTD proprietary adjustable frequency drive, this slow speed, high torque combination operates at variable speeds to maximize system efficiency and minimize noise. Perfect for new installations or for retrofitting older, less efficient cooling tower systems, the RPM AC Cooling Tower motor and VS1CTD Cooling Tower drive offers improved reliability while greatly reducing maintenance costs and energy consumption.

Check out our website for case studies, installation photos and additional information about the revolutionary new RPM AC Cooling Tower technology from Baldor. We are truly changing the future of cooling tower technology!

baldor.com/CoolingTower  479-646-4711

- Energy Efficient
- Unmatched Quality
- Superior Reliability
- Low Maintenance
- Quiet Operation
- Made in the USA
Mike Bickerstaff
Composite Cooling Solutions, L.P.

Abstract
There are several factors that need to be addressed prior to selecting the appropriate cooling tower fire wall for a facility with critical demands. Owners must give special consideration to the specifications of the fire wall system they are requesting for their cooling towers. Simply referencing a fire standard may not provide the owner with the finished product they desire or need.

This paper will review the systematic approach that should be followed when erecting an appropriate fire wall system. The paper will also review the test results from the full scale fire tests that were conducted for the purpose of providing information for this paper. Finally, the paper will elaborate on the special design considerations that are necessary to achieve a fire wall system that meets the design parameters, minimum maintenance requirements, and the extended service life that are being demanded for today’s critical cooling tower systems.

Background
Many of today’s cooling tower systems require specific deliberation to meet the significant requirements that are necessary for the cooling tower systems to operate efficiently and safely. Factors such as limited access, water supply, and material construction must be considered. In addition, cooling towers today are being placed not only in close proximity to other structures, but even on top of buildings. The concern for fire control has become a major consideration in cooling tower selection. This concern has increased the demand for fire resistant cooling tower systems.

Many owners and engineering design firms are following National Fire Protection Association 214 (NFPA 214) standards to meet the prerequisites for a fire resistant cooling tower. This in turn leads many individuals to the Annex A of NFPA 214 which is an attachment that provides clarification or explanation on some of the requirements of NFPA 214.

Annex A section A.3.3.6 discusses fire resistant partitions and gives examples that meet NFPA 214’s requirements for a fire resistant partition. The fire resistant partition examples are:

- ½ inch (12.7 mm) asbestos cement board
- ½ inch (12.7 mm) plywood
- ¾ inch (19.1 mm) tongue-and-groove boarding

Annex A goes on to clarify that each of these examples must be installed on both sides of the wood studs (framing structure). Annex A also states that other types of material must be tested in accordance with NFPA 251 to meet fire resistant partition requirements.

The problem that arises by simply installing one of the three approved partition examples listed in Annex A is that this will not meet the requirements set forth in NFPA 214 for a fire resistant partition. NFPA 214 - 3.3.6 defines a fire resistant partition (firewall) as a tight continuous partition suitable for use in a cooling tower environment that has a fire resistance rating of 20 minutes or more. This means that the fire resistance partition should not allow passage of flames or gases through any openings and/or cracks. The fire resistant partition should also control the passage of heat from one side of the partition to the other side of the partition by not allowing an increase of more than 250° F (140° C) above the initial ambient temperature.

Another reason that using one of the three approved partition examples listed in Annex A is not sufficient for a fire resistant wall is that the partition alone does not provide sufficient protection to be a fire resistant tower. Consideration must be given to the manner that the partitions are attached to the structural framing, as well as to the type of seal and caulking that will be used to close any openings, cracks, and seams. Fire resistant partitions will not block the passage of flames or gases nor will the partitions control the passage of heat without the appropriate attachment to the structural framing and the appropriate seal and caulking. Figure 1 illustrates that an approved partition example used as a fire wall partition must be used in conjunction with a suitable seal or caulking to ensure a fire resistant wall system. The cement board that was installed had problems that prohibited its effectiveness as a fire resistant partition.

- The openings around the FRP channels have not been sealed or caulked.
- The seams have not been sealed or caulked where the panels come together.

Erecting a Fire Wall System
During the design phase several factors should be considered before selecting a fire wall system.
The future of cooling towers, today.

**Pegasus** FRP Crossflow

**Phoenix** FRP Counterflow

**Phoenix** FRP Counterflow

COUNTERFLOW & CROSSFLOW DESIGNS ∙ FRP & CONCRETE STRUCTURE

**Architectural** Counterflow

**Concrete** Counterflow

Energy Efficient ∙ Environmentally Friendly ∙ Design and Layout Flexibility

Reliable Year-Round Performance ∙ Simplified Maintenance ∙ Quiet Operation ∙ Extended Service Life

NEW & REPLACEMENT INSTALLATIONS | REPAIRS & RECONSTRUCTION SERVICES | PARTS

**Patented Structural Design**

U.S. Patent No. 7,275,734

FRP components tested and lab certified for cooling tower use.

Customized cell sizes.

Utilizes proprietary resin injected at high pressure with fiberglass matrix, producing pultruded parts with superior structural properties.


4150 International Plaza, Suite 500
Fort Worth, Texas 76139-4826 USA

(817) 246-8700 • Fax (817) 246-8717

Toll-Free Parts Hotline (877) 887-7068

**Phenix** FRP Counterflow

Fire Protection Without Sprinkler System

Cooling tower designs that meet rigorous third-party testing for fire protection.

Helps owners ensure continued production, even in the event of fire.

Firewall test certification by Southwest Research Institute

The only cooling tower on the market that has 30-minute firewall rated assembly per ASTM E119.

No structural component considered sacrificial.

**CCSolutions**

Composite Cooling Solutions, L.P.
1. **Sheeting material** – Is the sheathing material that is used to enclose the structural members (framing) similar to the structural members? Example: ½ inch plywood sheathing would be appropriate for a wood frame cooling tower, but not for a fiberglass cooling tower because the two materials are not compatible for longevity purposes as the wood partition wall would require maintenance and/or replacement before the FRP tower.

2. **Method of attaching sheeting material** – Were the materials to be used to attach the sheathing material to the structural members selected to prevent potential problems during the installation process? Example: Screw or nail holes in cement board should be predrilled to prevent the screws or nails from cracking the cement board during installation.

3. **Sealing around structural members** - What is the allowable gap for sealing around structural members? Example: Is a ¼ inch gap allowable? ½ inch gap?

4. **Seals** – What type of seals will be used around the structural members? How much of a seal overlap will be required for the fire resistant partition?

5. **Fire Caulking** – What type of caulking will be used? Where will the caulking be placed: behind the seal, on the edges, or both locations?

6. **Spacers** – Will the sheathing material be installed with spacers or will the sheathing material be attached against the structural members? If the sheathing material is attached against the structural members, will a seal and caulking be used?

7. **Wall Space** – What will be the space between the walls? The greater the space, the slower the heat will transfer to the other wall. Different sheathing materials may require different spaces to pass the NFPA 251, ASTM E-119 fire test.

8. **Practical Design** – Is the design practical for installation in field conditions? Considerations should include: weather, restricted access, tower elevation, water absorption, etc.

**Full Scale Fire Tests**

Two fire tests were performed. The first test was conducted using ½ inch plywood as the sheathing material for the fire wall partition. ½ inch cement fiber board (CFB) was used as the sheathing material for the second test. Each type of sheathing material was attached to the framing structure with screws.

Purpose of the two fire tests:

1. Determine the suitability of ½ inch plywood and ½ inch cement fiber board as a fire resistant partition for field erected water cooling tower systems.

2. Determine the best methods of design and construction to maximize the fire resistance of the fire resistant partition.

3. Determine the fire rating of the fire resistant partition as required by NFPA 251, ASTM E-119 fire test.

The tests were not meant to determine what materials will pass or fail the NFPA 251, ASTM E-119 fire test. There are several other types of material that could be used for the sheathing of a fire wall partition, such as fiberglass or steel. Also the thickness of the sheathing material could be increased. Rather, the tests were conducted as a way to illustrate how important it is to test your design and installation procedures to determine if your fire resistive partition meets the standard set by NFPA 214.

The tests were designed by CCS and conducted by Southwest Research Institute Department of Fire Technology in San Antonio, Texas. A representative from FM Approvals was invited to observe the tests on an unofficial basis. Southwest Research Institute (SwRI) is an independent nonprofit applied research and development organization with a staff of more than 3,200 employees. The facility has two million square feet of laboratories, test facilities, workshops, and offices. FM Approvals is part of FM Global which provides comprehensive global commercial and industrial property insurance.

The tests were for a 20 minute firewall. The specimen required for this test must represent as closely as possible the actual conditions of construction in the field. The specimen must not be less than 100 feet² (9.3 m²) with neither dimension less than 9 feet (2.7 m). The test specimen must be restrained on all four edges.

The test will be considered valid if the specimen withstands the passage of flame and/or gases for 20 minutes and the transmission of heat through the wall during the test shall not be sufficient to raise the temperature more than an average of 250° F (140° C) above the specimen’s initial ambient temperature.

Fiberglass was the structural material used to frame the specimen for both tests. The fiberglass structure is composed of 3 inch square tubing for columns and 4 inch channel for the girts or ties. Stainless steel hardware was used for all connections.

**Fire Test 1**

The first wall tested was the specimen with the ½ inch plywood sheathing. The wall measured 10 feet by 10 feet. The structural frame was divided into two sections to allow evaluation of two different construction techniques, Section A and B, with each section measuring 5 feet by 10 feet. (See Figures 2a and 2b)
Blocks out Legionella virus in cooling tower!

New

Eco-anti virus LegioFree fill
and 3rd generation cooling tower

Now cooling tower aims at being eco-friendly!! LegioFree Fill!!

- ECO-DYNA COOL, new concept cooling tower with LegioFree fill.
- Would you still regard the cooling tower as a source of disease? LegioFree Fillexplodes the myth!
- Have no more worries about legionella virus and pathogenic bacteria emitted from cooling towers.
- Anti bacterial and disinfection function against various pathogenic bacteria reduces cooling water chemical treatment; another cost saving!
- To adopt LegioFree is an investment for the future.
- As LegioFree guarantees not only cooling tower performance but also more effective cooling system, it achieves energy saving by maintaining sound fill quality.

COOLING TOWER
Zip-code 400-037
53-1, 7ka Hang-Dong, Joong-Ku, Incheon, Korea
Tel: +82-32-695-9001 Fax: +82-32-695-9003
www.kimcoct.com sales@kimcoct.com
In the first section of the wall, Section A, the ½ inch plywood sheeting was attached directly to the 3 inch fiberglass column on both sides of the column. The plywood sheeting was abutted to the 4 inch channel. Fire caulking was applied where the plywood sheeting and the 4 inch channel met and where the plywood sheeting abutted to each other. This section had a 3 inch air gap. (See Figures 3a and 3b)

![Figure 3a](image1.png)

![Figure 3b](image2.png)

The plywood sheeting was cut around the 4 inch channels that pass through the wall. Plywood was then used to seal the openings. Fire caulking was used for all remaining openings or cracks where the plywood was not sufficient as a seal. (See Figures 4a and 4b)

![Figure 4a](image3.png)

![Figure 4b](image4.png)

A mid column was added to divide the 5 foot span of the plywood sheeting. 3 inch square tubing was used for the mid column. Reducing the plywood spans from 5 feet to 2½ feet helped to eliminate or control the unevenness of the plywood seams. (See Figures 5a and 5b)

![Figure 5a](image5.png)
Your tower represents a HUGE investment...
Isn’t it worth investing a small amount to keep it “in the Pink” by preservative spraying the wood structure?

PREVENTION is ALWAYS THE RIGHT SOLUTION!!!

Decay Prevention & Slime Control with PROVEN RESULTS
Nationwide Since 1964

Also Featuring:
- Fill Cleaning
- Fan Deck UV
- Protective Coating
- Dry Mothballing
- Wood Analysis
- Structural Inspections
- Spray-In Basin Linings

Spray Technician applying red dye colored preservative.

COOLING TOWER SOLUTIONS
by Spraying Services, Inc.
Phone: 713.941.1944 • Fax: 713.941.2545
www.sprayingservices.com
In the second section of the wall, Section B, the ½ inch plywood sheeting was attached with fiberglass spacers. The spacers were added to level the columns with the horizontal members. Once again the plywood sheeting was cut to fit around the 4 inch channels that passed through the wall. Plywood was used to seal the openings, and caulking was used for all remaining openings or cracks where the plywood was not sufficient as a seal. This section had a 5¼ inch air gap. (See Figures 6a and 6b)

In Section B a midpoint ½ inch plywood gusset was installed because the 5 foot span of plywood sheeting once again posed a warping problem and caused uneven seams. Caulking was applied along the seams and the gusset. (See Figure 7a and 7b)

After Sections A and B were completed, the ½ inch plywood wall specimen was attached to the furnace frame. Then the frame was attached to the vertical furnace with its nine gas burners. Thermocouples were attached to the wall specimen at this time. The wall specimen was now ready to be fire tested. (See Figures 8a and 8b)
ChemTreat, the new direction in industrial water treatment, introduces these innovations to the market place:

- New Phos-FREE (non-phosphorous) all organic inhibitor technology
- PolyTrak® actives based monitoring and control for on-site system performance optimization
- Quadraspense® patented quadpolymer technology that dramatically improves corrosion and deposit control in high stress water treatment applications

Better Performance, Bottom-line Savings.

Each of these innovations is a unique way of improving system performance with cleaner, longer-lasting equipment. You reduce maintenance costs and minimize unscheduled shutdowns.

Breakthroughs like these join a growing array of components and capabilities that we configure to maximize your particular water management and control systems.

Satisfied Customers.

Innovative technology combined with the experience and stability of our sales representatives, has earned ChemTreat the lowest customer attrition rate in the industry: 2% versus 15-20% for our competitors.

By forming a partnering relationship with our customers, ChemTreat delivers the best possible products and services for your specific applications.

We will be glad to prove it to you with a systems survey and our cost-saving recommendations.

An ISO 9001 And An ISO 14001 Certified Company

ChemTreat, Inc.
4461 Cox Road-Glen Allen, Virginia 23060
Phone: 804-935-2000 Fax: 804-985-6974
www.chemtreat.com
Southwest Research Institute monitored all of the construction process for the wall specimen to be fire tested. During the fire test, SwRI recorded the data collected from the thermocouples every 15 seconds. (See Figures 9a and 9b)

**Fire Test Requirements**

- 30 inch deep vertical furnace
- Flame burners symmetrically placed across the back of the furnace
- Furnace temperatures are controlled to a time and temp curve up to 1700°F
- External firewall surface is measured with a minimum of nine thermocouples
- The external temperature cannot exceed an average of 250°F above the ambient temperature
- No breakthrough of fire is allowed

**Fire Test Results for ½ inch Plywood Sheeting**

- At the 6 minute 10 second mark, both sections of the wall specimen had failed the fire test. (See Figures 10a, 10b, 10c, and 10d)
SAFETY + RESULTS = TRUST

It’s a Formula That’s Made Marley an Industry Leader for Safety

» 2007 and 2009 Thomas J. Reynolds Award for construction safety from The Association of Union Constructors
» Southern Company - Triangle Safety Award
» Dow Freeport - 10 years no recordables
» Exxon Mobil Baytown - Outstanding Performance Award - 11 years no recordables
» KCP&L Ivan Power Plant - two time Contractor of the Month for safety
» Sunoco - 2008 and 2009 Certificate of Excellence for recordable rate < 0.25
» The Greater Houston Chapter of Associated Builders and Contractors - The S.T.E.P Platinum Award

There is simply no substitute for safety, and who could argue with Marley’s safety record. Marley logged over two million man hours globally in 2009, both open and closed shop — yet thanks to a world-class safety process, Marley’s open-shop Total Recordable Incident Rates (TRIR) was only one-fifth of the industry rate.

At Marley, safety is no accident. In fact, Marley has been recognized time and again for outstanding safety achievement. And greater safety means faster project completion as well as lower installation costs for our customers. And that’s something we’re proud to hang our hats on.

1.800.462.7539 | spxcooing.com
Figure 10b. Time was 6:10
Figure 10b shows the fire break through where the plywood sheeting abutted to the 4 inch channel. There was no seal over the channel, only caulking was used to close the openings.

Figures 10c and 10d were taken at the same time frame, but 10d has been enhanced to remove some of the smoke for a better view of the wall. The fire has broken through where the seams of the plywood sheeting was caulked but not sealed.

- The side of the plywood sheeting that was exposed directly to the flame was completely gone at the 6 1/2 minute mark. (See Figure 11a and 11b)

Figure 11a

Figure 10c. Time was 6:32

Figure 10d. Time was 6:32

Figure 11b

Figure 11a shows the ½ inch plywood wall specimen still attached to the furnace frame, but moved away from the vertical furnace. Figure 11b was taken after the wall specimen had been extinguished and allowed to cool.

- The plywood sheeting that was not directly exposed to the flame (the outside sheeting) first showed failure at the seams. (See Figures 12a and 12b)
The Industry's Most Trusted Source in Components!

Dynamic Fabricators

We are known for providing dynamic solutions resulting in quality advantages and competitive pricing. Providing excellent customer service is our #1 priority. It's what keeps our customers coming back.

Your Complete Cooling Tower Supply Source
- Header, Bypass, Riser and Lateral Distribution Syst.
- Fan Stacks, Fan Ring, Inlet Belts, FRP Basins.
- Fiberglass Saddles, Distribution and Splash Boxes.
- Pultruded Fiberglass Fabricated Components.

Texas Facility has a full line of components and services available for pickup – or we deliver to job sites.

Your dynamic partner in cooling tower components...

Dynamic Fabricators

Toll-Free 877.604.6525 • Texas 281.456.8080
www.dynafab.net • www.AmtechCorp.com
Figure 12a. Section A

Figure 12b. Section B

Figure 13a. Section A: 3 inch Air Gap

Figure 13b. Section B: 5¼ inch Air Gap

Fire Test 2
The second wall tested was the specimen with the ½ inch cement fiber board (CFB). The wall measured 10 feet by 10 feet. (See Figure 14)

Figure 14. Fiberglass Structural Framing for ½ inch Cement Fiber Board Sheeting
MIDWEST TOWERS
Leading the way in quality, service, and value.

**Midwest Towers** leads the way for you with a full range of cooling tower products and services for your project. We are a complete cooling tower supply company. Our skilled and experienced team can support you in every step — design, fabrication, installation.

Contact us today and see how much value we can bring to your cooling tower project.

- Crossflow & counterflow cooling towers with wood or FRP structures
- Custom lumber fabrication and treating
- Fiberglass fan stacks and water distribution systems
- Non-skid fiberglass fan deck and hot water basins
- Corrugated FRP casing and louvers
- Fans, gears, drive shafts, motors, supports
- Flow control valves, nozzles, grommets
- Fill and drift eliminators
- Hardware, brace connectors, base anchors
- Replacement parts for all models and manufacturers
- Budget optimization and thermal upgrade studies
- Complete engineering services
- Reconstruction and thermal performance upgrades
- Maintenance and service contracts
- Emergency response and repair

www.midwesttowers.com
PO Box 1465 • Chickasha, OK 73018
Tel 405 224 4622 • Fax 405 224 4625

Sales Offices in New Jersey, Florida, Missouri, Texas & California
Rep Offices throughout the country
The ½ inch cement fiber board was attached directly to the column across the entire structural frame. The wall was not divided into sections. The cement fiber board sheeting was abutted to the 4 inch channels and adjacent cement fiber boards. All seams were closed completely with two passes of caulking as the first fire test proved that this area on the wall specimen was a failure point. (See Figures 15a and 15b)

The cement fiber boards were cut to fit around the 4 inch channels that passed through the wall. Cement fiber board was then used to seal openings, and caulking was applied to any remaining openings or cracks. This wall specimen had a 3 inch air gap. (See Figures 16a and 16b)

Since the fire test with the ½ inch plywood sheeting had showed extreme failure at the seams of the adjoining sheeting and where the plywood abutted to the channels, 6 inch wide cement fiber board seals was attached over the seams of this wall specimen. Caulking was then applied. A heavy bead of caulking was applied to the areas where the cement fiber boards were cut to fit around the channels. (See Figures 17a and 17b)
Reliable Electronic Vibration Switch Protection at the Price of a Mechanical Switch!!!!

New Series 686B Smart Vibration Switch is now more cost-effective than ever and fully USB programmable from any PC. With two-wire operation, it is simple to install and a drop-in replacement for troublesome mechanical switches. With Remote Reset Anywhere™, you can install the reset button at any convenient location in the existing two-wire loop. This unique, low-cost vibration switch replaces most mechanical or electronic switches.

- Precision measurement of vibration velocity
- Power on, startup, & operational, delays
- Normally open or closed, latching or non-latching
- Universal 24 to 240 VAC/DC power
- SPST 0.5A contact with easy extension to DPDT@10A
- Hermetically sealed for harsh environments
- MAVT™ automatically sets alarm level

Call us today to learn more about the Smart alternative to mechanical vibration switches!
Once the wall specimen construction was complete and the wall was stood, all seals and interface points were inspected. Additional caulking was applied as needed.

The ½ inch cement fiber board wall specimen was attached to the furnace frame. Then the frame was attached to the vertical furnace with its nine gas burners. Thermocouples were attached to the wall specimen at this time. The wall specimen was now ready to be fire tested. (See Figure 18a and 18b)

Southwest Research Institute monitored all of the construction process for the cement fiber board wall specimen to be fire tested. During the fire test, SwRI recorded the data collected from the thermocouples every 15 seconds. The fire test requirements were the same as for the first fire test. (See Figures 19a and 19b)
Optimize your tower or plant performance and profitability.

McHale is the industry leader in plant performance evaluations for cooling towers. Contact us today for a quote or visit us at www.mchale.org.

Contact the performance specialists.

McHale & Associates, Inc.
www.mchale.org
Noreen Florio, Proposal Manager
17720 NE 65th Street, Suite 200, Redmond, WA 98052
Phone: (425) 883-2058  Fax: (425) 881-8480
noreen.florio@mchale.org
Fire Test Requirements
- 30 inch deep vertical furnace
- Flame burners symmetrically placed across the back of the furnace
- Furnace temperatures are controlled to a time and temp curve up to 1700° F
- External firewall surface is measured with a minimum of nine thermocouples
- The external temperature cannot exceed an average of 250° F above the ambient temperature
- No breakthrough of fire is allowed

Fire Test Results for ½ inch Cement Fiber Board
- The ½ inch cement fiber board wall specimen passed the 20 minute fire test. (See Figures 20a and 20b)
- After the test was complete, the side of the cement fiber board sheeting that was exposed directly to the flame was almost completely gone. (See Figures 21a and 21b)
- The cement fiber board sheeting that was not directly exposed to the flame (the outside sheeting) was intact.
- Even though the ½ inch cement fiber board wall specimen passed the 20 minute fire test, there were visible flames where the cement fiber boards abutted to the channels. The flames showed through at 20 minutes 18 seconds. This illustrates the importance of the fire test and the test results. Without the additional caulking the wall specimen may have failed the test. (See Figure 22)
You could if you wanted.

Stay in touch from virtually anywhere with VTouch® Remote Site Manager

The WebMaster® water treatment control system delivers access absolutely anywhere the internet can reach. Installation is a breeze, and the time-tested VTouch® Remote Site Manager won’t leave you in midair when trouble hits.

Rock solid remote access, as close as your browser.
The industry’s first web-based water management control system has evolved to reach new heights of power and user friendliness, thanks to features that system management contractors can trust:

- Seamless start-up and operation
- Monitoring, control, data logging and alarms
- Your choice of connection methods: network, USB, phone and more
- Totally browser-based software

So go ahead. Take the plunge with WebMaster, the system that makes sure you hit the ground running.

For more information: www.walchem.com / 508-429-1110
Design Considerations for a Fire Wall System

- The greater the space between the two walls of sheeting material that encloses the structural frame, the greater the thermal reduction.
- To reduce warping of the ½ inch plywood sheeting, the span between the structural supports should be reduced and/or a wide seal strip should be placed over all the seams with caulking applied at all openings.
- Fur (shim) the structural columns far enough out so that the sheeting will past over the horizontal channels. By doing this, it will reduce the number of interface points (seams) that will need to be sealed or caulked.
- If the structural columns cannot be spaced further out, then another option would be to use some type of gusset that would be applied over the interface points.

Instead of constructing field gussets, plan ahead to have the gussets fabricated in the factory for an exact fit.
- When cutting the notch to fit around the channel, a guideline that has been pre-determined by the engineer of the cooling tower system must be followed so as to not make the opening larger than necessary.
- When selecting the sheeting material that encloses the structural frame, be sure to select a material that is compatible with the structural framing so that maintenance and service life will not be compromised. The sheeting material should not have a greater degree of service or maintenance issues than the other components that make up the fire wall system.
- There needs to be a comprehensive inspection form that will verify the proper installation of all the critical elements that are necessary to build a fire resistant wall system.

Conclusion
With the increasing demand for fire resistant cooling tower systems, numerous questions regarding the specification of fire resistant walls have arisen. Just as with any other cooling tower system, a fire resistant wall system must begin with a design that has been engineered to meet the requirements of the owner. The tower designer must then comply with the NFPA requirements that are provided in the NFPA 214 and 251. Once a design has been engineered, a fire test is the only way to verify that the wall is indeed a fire resistant wall.

References
we add value to your business

- Construction, reconstruction and repair of Cooling Towers and equipment for the treatment of industrial water
- Cooling Tower technology supplies
- Supply, repair and installation of Microcoolers
- Supply, repair and installation of Ventilators for Cooling Towers
- Production of equipment for cooling and cleaning industrial water
- Preparation and processing of technical drafts
- Purchase of goods for resale and sale
- Research and development in the area of natural and technical sciences and social sciences
- Testing, measuring, analyses and controls
- Technical consulting activities in the area of cooling and cleaning industrial water

THE PRAGUE OFFICE:
FANS, a.s.
Lomnického 9, 140 00 PRAGUE 4
Tel.: +420 234 718 900, Fax: +420 234 718 918
E-mail: praha@fans.cz

THE HLINSKO OFFICE:
FANS, a.s.
Ležáků 231, 539 01 HLINSKO
Tel.: +420 469 312 460, Fax: +420 469 311 367
E-mail: info@fans.cz
What Is The Best Water Treatment Program For My Tower

Robert J. Cunningham
Arthur Freedman and Associates

Abstract:
One of the most frequently asked questions received by the CTI “Ask the Expert” department is “What is the best cooling water program for my cooling tower?” This question comes up so often that CTI has decided to dedicate a panel discussion to the subject, as well as to solicit papers on the topic.

The best answer to this question is “it depends”. Many factors should be considered in the decision regarding the proper treatment for any open recirculating cooling tower system. The relative severity of each factor must be considered in order to arrive at the optimum solution for each case. There is no “one best fits all” when selecting the optimum treatment, and there is no substitute for a thorough understanding of all of the factors that surround this selection process. Ignore this maxim at your peril!

Background:

Cooling towers are employed to reject heat to the atmosphere from one or more processes. While the cooling tower itself is a very important component of an integrated cooling system, it is just one component. In addition to the tower itself, there is the process(s) that provides the unwanted excess thermal energy, or heat, and there is the associated infrastructure, including the associated pumps, valves, and recirculating water piping. Frequently a cooling tower is rejecting heat from multiple processes, each with its own associated equipment, and its peculiar set of pre-ordained considerations, including heat transfer design considerations, metallurgy, etc.

Cooling towers, evaporative condensers, or closed circuit coolers accomplish almost all of the desired cooling effect by evaporating a portion of the recirculating cooling water. This requires a continuing source of supply, or “make-up” water to replace that lost to “evaporation”. When evaporation occurs, pure water vapor is lost from the system. This evaporation causes the dissolved solids that were originally present in the make-up, or source water, to concentrate in the remaining system “recirculating water”. If this process of concentration is not interrupted or limited, the solubility of a range of dissolved sparingly soluble compounds will be exceeded, and precipitation will result in sludge formation and probably lead to scale formation. We limit the concentration process by “blowing down”, “bleeding off”, or removing a portion of the concentrated cooling water. This requires more make-up water.

In addition, a variable amount of the recirculating water is lost from the system due to “windage” or “drift” loss due to carryover of entrained water droplets in the mass flow of exit air. This amount will vary greatly due to environmental conditions, tower maintenance, treatment chemical selection, and the efforts of each manufacturer to minimize “drift” by providing “drift elimination”. In addition, in real world systems there is always some amount of water loss due to “leakage”, or unintentional water loss due to miscellaneous leaks of water from the system piping and equipment. In some plants cooling water is intentionally used for various plant “wash down” purposes.

In order to provide the make-up water required to replace that lost due to evaporation, blow-down, drift, and leaks, these systems also, by extension, incorporate a make-up water supply system of varying complexity, and a blow-down treatment/disposal system that will again vary in design and operating complexity. Because the cooling tower depends on evaporation to accomplish the cooling duty, and requires intimate contact of the water with copious quantities of air, there is also ambient air quantity and quality that must be considered. Depending on where the cooling tower is installed, and on the availability of one or more sources of make-up water, as well as on prevailing climatic conditions, make-up water quantity and quality may vary over time, and blow-down discharge restrictions may also vary from location to location, as well as over time.

From a chemical treatment point of view, the ideal cooling tower water system would incorporate equipment of relatively simple construction, with all materials selected to exhibit minimal deterioration in the system operating environment. Heat transfer surfaces would employ very conservative design flows with lots of surface area, in order to minimize unit heat flux and exchange surface skin temperatures. Such an ideal system would employ high quality stable make-up water, and low cycles of concentration. In addition, the system would be equipped with generously sized side stream filtration to minimize suspended solids loading in the recirculating water, due to suspended matter present in the make-up, or carried to the tower by the ambient air, or by process streams.

Metallurgy would be selected to minimize corrosion. Sacrificial or impressed current anodes might also be installed. Cooling tower components would be selected to minimize deterioration, and tower fill would employ open splash bar construction resistant to fouling. The recirculating system would be equipped with a very reliable pH, cycle of concentration, and oxidant control system. All chemicals would be fed based on make-up flow and trimmed based on a specific ion control program. On-line analyzers would analyze continuously for all critical parameters, not for convenient but possibly misleading proxies, and control results would be entered onto a web based data base in real time, so that operators and management would be able to insure convenient and continuous long term real time, stable and reliable operation that is continuously within optimum control limits to achieve efficient operation with minimal heat transfer losses, minimum maintenance expense, and maximum reliability.
Such a system would be close to ideal from a chemical treatment point of view, possibly not requiring any corrosion inhibitor, instead receiving an appropriate oxidant for microbial control, along with a reversion resistant scale control agent(s), possibly some surfactant to aid in microbial control, some antifoam to minimize windage, and if necessary, some organic copper corrosion inhibitor to control background corrosion of copper bearing alloys, if present.

While such a system would be very easy to treat from a chemical point of view, and it would require very little operator attention, it would bear very little resemblance to the real world, as we find it today.

In today’s economic and competitive environment, the players within our industry (designers, manufacturers, component suppliers, regulators, and bean counters) have been very busy creating the perfect storm! We are now living in an environment where we have optimized heat transfer surface efficiency, minimized footprint, minimized drift, optimized fill efficiency, and reduced operating budgets to the point where the unsuspecting owner/operator may find himself operating a system designed with no room for error, with a maintenance and operating budget that is inadequate to insure long term reliable operation. At the same time we are pushing plants harder and longer, and running for extended time periods with process leaks, and without adequate time to schedule routine maintenance and system turn-around inspections.

Factors Affecting System performance:
Against this background, our question, “what is the best treatment?” takes on special meaning, as we may well be facing the more appropriate question of “under what circumstances can my system be successfully treated?”, or what must I do to be able to treat the system successfully over the long haul?” Let’s start by asking ourselves “what information do I need in order to determine if the system can be successfully treated?” In order to make this process relatively easy, let’s look at the system, component by component, to see what information is available, and what more we need to know. Let’s conduct a thorough system survey. Unless the process heat transfer equipment has been properly designed, we have very little chance of successfully treating the system over the long haul. For this reason, let’s start our survey with the process heat transfer equipment.

Process Heat Transfer Equipment:
The inventory of process heat transfer equipment is very broad indeed. Depending on the industry in question, the heat transfer equipment can vary greatly with respect to the type of and variability in installed equipment, specific design considerations, complexity, metallurgy, water flow rates, turbulence, and linear flow velocity, heat flux, exit water temperature, equipment skin temperature on the heat transfer surface, etc. We have to ask ourselves what industry (HVAC, power production, petro-chemical, refining, oil production, food processing, iron and steel production, etc.) we are dealing with. Within each industry we need to find out which processes are involved? For example, within the iron and steel industry, are we talking about blast furnace cooling, continuous caster cooling, scarfing, quenching, surface condenser cooling, etc.? To further define what specific conditions we might expect, we need to further define each unit process, for example within the blast furnace area, are we talking about tuyere cooling, furnace door cooling, etc.? Each different type of specialty cooling device or sub-process will have inherent design, metallurgy, flow, and temperature considerations that must be well known and well understood by the person who is selecting the cooling water treatment program. Tuyere cooling refers to the water cooling of hollow copper distribution tubes supplied at regular intervals within the blast furnace for the purpose of distributing the “blast” within the furnace.

The refining and petrochemical industries frequently employ “shell side” heat exchangers, with the cooling water flowing through the exchanger shell, and the process fluid flowing through the tubes. Unless these exchangers are very well designed, with proper baffling and fluid flows and process temperatures carefully controlled to achieve the conditions for which the exchanger was designed, low velocity regions on the shell side can result in severe scaling and/or corrosion. It is also quite common for changes in operating conditions, such as process side flow changes to achieve changing or up-dated process temperature requirements dictated by process economics, to result in insufficient or in excessive flows on the process side, which can result again in problems on the cooling water side. Other industries employ specialized heat exchanger designs, such as vertical heat exchangers, which can result in solids accumulation due to the orientation and operating conditions of the exchanger. Each industry presents unique applications that must be fully understood to avoid common pitfalls.

All of this information bears directly on which specific problems, with what specific severity, must be solved. Some aspect of the chemical selection, dosage determination, and control determination process may well need to be “tweaked” in order to achieve good over-all results. In addition, all of this information will guide us in the selection of monitoring processes, locations, and frequency, and in the design of the data management system.

Exchanger Design:
Are the exchangers designed so that the water and process side heat transfer surfaces are easily inspected? Can the process and water side of the exchangers be easily cleaned and inspected after cleaning to verify results? Are exchanger process and water side flow rates sufficient to provide for turbulent flow and sufficient linear velocity at all points along the heat transfer surface to minimize fouling and deposition due to settling of particulate solids and deposition of scale (5 ft/sec, with 3 ft/ sec as a minimum possible flow rate in the case of water side)? Have provisions been made for reverse flow flushing or air/inert gas bumping? Is cooling water mass flow rate sufficient to provide enough flow to insure turbulent flow conditions at the exchange surface and to carry away enough heat to limit exchanger exit skin temperature to a level that can be treated successfully for scale and corrosion control given the discharge limits in play? Is this true for all of the various parallel and series installed equipment?

Metallurgy:
What specific alloys are contacted by cooling water and/or process side products? What alloys are galvanically coupled? Are the metals and alloys present properly selected for both the cooling water and the process side environments? If dissimilar metals have been used, are they properly electrically insulated, or close enough on the electromotive series that significant galvanic attack will not occur? Has any high voltage equipment been improperly grounded on this equipment? Does any of the equipment that is being cooled operate with high voltage equipment, requiring special attention
What Fiberglass Cooling Tower is All About

Model ST: Prevailing wind directions will not affect cooling performance due to the unique circular design on the cooling tower. Lightweight and compact to eliminate heavy support and space requirement. Finally, a cooling tower provides quick and easy installation.

Model LRC-H: A crossflow cooling tower features lighter operational weights and reduces space requirements. Future expansion is achievable with adaptation to the existing towers. Multi-cells designed to accommodate seasonal cooling needs.

Model LHC: A crossflow cooling tower specifically designed to serve industrial application which demands dependability and durability of the towers.

Contact information: www.amcot.com

Amcot Cooling Tower Corporation 350 N. Ponderosa Avenue, Ontario, California 91761
Phone (909) 390-2598 Toll Free (800) 444-8693 Fax (909) 390-1098 Email: amcot@aol.com
to water chemistry, or special attention to conductance of cooling water piping materials and cooling conduit hose lengths in order to prevent stray current grounding through the cooling water column and conduits?

**Heat Transfer Surface Skin Temperatures:**

Most detrimental reactions (corrosion, scaling, fouling, microbial growth) are exacerbated due to increasing temperature. As cooling water side skin temperatures rise, the driving force behind most of these reactions increases, requiring progressively better chemical treatment and control. In general the rate of many of these reactions will double for every twenty degrees C that the temperature increases. As skin temperatures start to exceed 120 degrees F, many inhibitors begin to show marked reductions in efficiency. Above 140 degrees F, even the best corrosion inhibitors become highly strained, and dramatic failures may result. Are all exchangers equipped with a means of measuring inlet and outlet fluid flows and temperatures? If critical exchangers are present, are provisions made to measure cooling water maximum skin temperature? On the other hand, are flows so high that failures from erosion and/or vibration induced cracking must be anticipated?

**Cooling Water/Process Fluid Flow Considerations:**

The system should have originally been designed with particular cooling water, process flow, and air flow conditions provided. These flows should be periodically checked to insure that none of these flows have changed due to factors such as abraded or corroded pump impellers, blocked or partially blocked valves and piping, construction that blocks air flow to and from the cooling tower, the addition to the system of new or re-designed heat transfer devices, or intentional bypassing of either cooling water or process fluid around an exchange(s). On many process cooling systems, recirculating water pumps have been so closely sized that even the installation of a corrosion coupon bypass on the return water to the tower or condenser can result in too little cooling water flow, and can result in improper water distribution through the cooling unit. Don’t forget to look for improperly wired recirculating pumps. Some pumps will run in reverse if improperly wired, and this will cause large flow disruptions.

**Cooling Tower Design:**

There are many aspects of cooling tower design that can affect the ability of the tower to reject the necessary system heat load. Many other aspects affect the degree of maintenance required, as well as the frequency of maintenance. In order for the system to function effectively, the recirculating cooling water and the inlet cold air supply must achieve intimate contact in order to effect maximum evaporation.

This is normally achieved by providing for an excess of air flow by means of either density difference (hyperbolic towers), or by means of installed fans to either blow air through the tower (forced draft), or suck air through the tower (induced draft). Hot return cooling water is then sprayed over the tower fill, or cascaded over the fill, counter current to the cold air supply. In order to achieve maximum cooling efficiency, both the air flow and the water flow should be relatively uniform across the tower. This is accomplished by means of the water distribution system, and by the spacing achieved across the fill to allow uniform air flow. In general, the less efficient this process is, the more cross sectional area is required in order to accomplish the same cooling load. Towers accomplish this task by providing for water distribution by means of distribution basins on the top deck of the tower. These basins are designed to provide sufficient depth in the distribution basin to provide sufficient head to efficiently operate the distribution nozzles installed in the bottom of the distribution basins. Alternatively many towers depend on a header and lateral system with spray nozzles installed above the fill. In a specialized design, a heat exchanger is installed in the tower itself, where the fill would go in a conventional tower, and the tube bundle replaces the fill, with the tubes acting like splash bars in a conventional fill arrangement. This modification is called an evaporative condenser or closed circuit cooler.

**Fill:**

In recent years, the splash bar type fill has in many cases been replaced with “film pack” fill, which consists of sheets of corrugated rigid plastic that are layered upon one another. The geometry of the extruded plastic sheets affects both air and water flow, and exposes maximum water surface area to the air flow. While this type of fill can be very efficient, there are many fine passages involved in the design, and if too little water flow is provided in one or more areas of the fill, evaporation results in over-concentration of the cooling water, causing solubility products to become exceeded, and scaling and fouling to result. This can result in deposition on and plugging of the fill. This process of fouling and eventual “blinding” over the fill open space is called “bridging”.

Once the surface of the fill is roughened by scale formation and/or microbial accumulation, then the degraded fill surface texture becomes a site for rapid accumulation of suspended solids, as well as more scale formation. The resultant mass of accumulation can not only block airflow from portions of the fill, but it can also result in complete collapse of the fill, due to the weight of the accumulated solids. While film pack fill is relatively inexpensive and very efficient, it is easily fouled, and once fouled, very difficult to clean. For this reason, the presence of such fill places special limitations on the water treatment program, and unless the supply water is of very high quality, and the ambient air is very clean, its presence will dictate the use of bypass filtration to remove all suspended particulate matter. It may also dictate operation of the water treatment at a lower pH than would be the case with splash bar type fill.

Each installation should be evaluated first for the presence of suspended solids in the air supply (dirt, dust, sand, plant fibers) as well as in the water supply (mud, silt, and other particulate materials). If these materials are present, they must either be removed by means of filters, or film pack fill might not be the best choice. In addition, if the tower will be subject to high cycle operation due to water shortage or to environmental restrictions on blow down, then film pack fill selection must again be questioned. I believe that any system equipped with film pack fill is a candidate for a good multimedia bypass filter. Sizing, materials selection, and operation of bypass filters is a topic best left for another time, but in general, I recommend a bypass filter capable of handling a minimum of 2% to 5% of the recirculating water. If film pack fill is used, then special attention must also be paid to microbial control, and the fill should be inspected and cultured periodically for signs of bio-accumulation.

In areas of the country that are subject to periodic high velocity catabatic wind storms, such as the famous Santa Ana winds of Southern California, consideration should be given to sizing side stream filters.
Reliability. Guaranteed!
Since 1974

Fiberglass Cooling Tower
Structural Components & Products
Ladders // Hand Rails // Grating // Decking

Visit us Online! www.bedfordplastics.com

frpsales@bedfordplastics.com
264 Reynoldsdale Road // Bedford, PA 15522-7401
When things heat up, call Aggreko.
Aggreko Cooling Tower Services (ACTS) is the world’s largest provider of **rental cooling tower solutions**. For over 20 years, we have successfully helped customers solve their cooling water limitations - under any circumstances.

From the planning stages to the turnkey installation of convenient modular cooling towers, ACTS has the solutions to help you keep your cool, **24/7/365**.

ACTS provides proven rental cooling tower solutions to:

- Overcome thermal discharge temperature limitations
- Minimize post-disaster downtime
- Maintain cooling capacity during partial or complete tower repair
- Lower cooling water temperatures and reduce turbine back-pressure
- Add cooling water capacity with no capital commitment

Contact Aggreko today for all your rental cooling tower needs. Call us at **866.215.7963** or visit us online at [www.aggreko-cooling-tower-rentals.com](http://www.aggreko-cooling-tower-rentals.com).
to handle sufficient flow to rapidly remove sudden heavy loads of suspended matter, including course dense sand.

**Tower Basin:**
The design of the tower basin governs how much excess water the system is capable of holding. At times plants will select deep basin towers, primarily to allow for additional fire fighting water in an emergency. All tower basins are more or less subject to accumulating suspended solids and microbial growth. As deeper basins are selected, all else being equal, the system volume and holding time index goes up. This means that the water will be in the system longer, and it means that the chemicals chosen to treat the system must be more reversion resistant, and the film formed must be more tenacious. In other words, the chemicals have to last longer in the desired form, and be less resistant to degradation due to time, temperature, and the influence of oxidizing microbiocides and process contaminants.

In my opinion, deep basin, high holding time index systems are all candidates for side stream filtration, and they should all be equipped with a reliable system for adding oxidizing microbiocide into the bottom of the basin. In addition, if such a system experiences a process leak, it should be immediately repaired, or the system must be carefully inspected and treated to insure freedom from accumulation of process contaminant degradation products and microbial growth, especially in the basins. I also believe that all such systems should be equipped with a system of headers and laterals to inject water containing oxidizing, as well as non-oxidizing microbiocides, and possibly surfactants, uniformly across the back of the basin, so that the chemical sweeps across the basin at the bottom on its way to the recirculating pumps. Any plant with a deep basin tower system should be subjected to periodic basin inspection and if necessary, the basin should be either cleared of suspended material mechanically during shut-down, or it should be cleaned on line using vacuum systems, possibly employed by divers equipped with SCUBA gear.

**Recirculating Pumps:**
And now a word about recirculating pumps! Many such pumps are subjected to incorrectly fed and diluted acid and oxidant, present at excess concentration at the pump itself. These pumps also frequently have brass or bronze impellers, and they are subject to corrosion, as well as to mechanical erosion, due to suspended solids. Such pumps should be equipped with flow measuring devices, and they should be inspected at least every turn around or earlier if flow concerns arise. Without adequate water flow, critical exchangers are frequently doomed to rapid fouling with scale, suspended solids, microbial growth, and corrosion products. Under such conditions, the corrosion inhibitor program will most likely fail as well. While our modern “green” treatment products have many good features, it is important to remember that they have some real water chemistry related limitations, and they may not be as effective, corrosion wise, as the older products that we relied on for many years.

**Tower Fans:**
Design of tower fans is outside the scope of this paper, but it must be remembered that the fans are the primary drivers for air flow. Anything that affects the efficiency of the fans is likely to reduce air flow. Without good air flow, the tower performance, and hence the efficiency of the entire heat rejection system, will suffer. Tower air flow measurement should be periodically checked to insure proper performance. Also consider existing or new construction in the vicinity of the tower. It is not at all uncommon for a large new structure in the vicinity of the tower to block air flow.

**Air Quality:**
The ambient air quality over time can have a significant impact on the entire system. Is the system subject to continuous or periodic air contamination? (Consider sand storms, catabolic winds, contamination from a neighboring stack or process air emission). I have seen Santa Ana winds in Southern CA completely load up a very large, very critical cooling tower system with dirt, dust, and with loads of sand and plant fibers. The system is located in a large coastal refinery within the confines of a large city. I have also seen a rooftop package tower that was being quickly stripped of its protective coatings due to the proximity of an exhaust stack from paint spray booths where MEK solvent was in use. In addition, I have seen pH control programs completely overwhelmed by the presence of acid gasses from a neighboring combustion exhaust stack, with pH levels dropping to close to 4.0.

**Tower Support Members:**
At one time, most cooling towers were constructed of heart redwood. As this high quality wood became more costly and scarce, less desirable types and grades of wood were used. Today there is a great deal of metal, plastic, and ceramic used in the construction of towers. All materials have advantages and disadvantages. Wood construction makes the tower vulnerable to microbial attack of various kinds. Metal towers are subject to corrosion. Ceramic towers tend to be quite costly, and the use of ceramic materials places design limitations on construction. If wood is used in a given tower, the inspection program must incorporate periodic inspection by a qualified person to look for the various types of deterioration that can occur, and the water treatment program must incorporate specific control for such organisms. If metal is used, the inspection program must look for corrosion, and the corrosion control portion of the water treatment program must incorporate specific treatment to protect the tower metal, as well as the exchangers and system piping.

**Make-Up Water Quality:**
Now let’s take a look at the impact of available make-up water on the performance of the system. The composition of the make-up and our responses to it in terms of program selection and control responses will have a great deal of influence over the success that we achieve.

Many areas of the world are cursed with rapidly varying make-up water quality. Systems receiving make-up water directly from surface streams and lakes are subject to large variations in suspended solids, as well as to variations over time in water chemistry. Systems receiving well water supply usually do not have a big suspended solids problem due to solid material entrained in the supply water, but they are frequently limited by water that is very high in hardness, sulfate, chloride, and alkalinity. In addition, well waters in many areas contain high and variable levels of silica, manganese, and iron. Well supplies are usually quite constant in composition, but many locations must pull their water from a large number of low volume wells, with each well exhibiting markedly different composition. Such is often the case in areas that are relatively geologically active, or that have been in the recent geological past, with attendant fracturing and faulting. A third rapidly growing source of make-up water is the use of reclaimed industrial process or municipal waste water. Reclaimed waste water is frequently contaminated with
The industry's most complete line of quality cooling tower products ... for the smallest HVAC towers to the largest natural draft towers ... leading the way with enviro-friendly innovations like non-glue Mechanical Assembly and anti-microbial AccuShield Products.
process and metabolic constituents. The consistency of this third source will depend on the type of process(s) that is generating the reclaimed water.

Each source of make-up should be carefully studied, paying particular attention to variability in chemical composition and contamination over time. Changes in composition and contaminants over time must be carefully addressed by the control and treatment chemistry, and may require supplemental pre-treatment of the make-up source to mitigate the variability and contamination to prevent operating problems that might arise due to these causes.

Systems that receive water that is high in suspended solids should be equipped with good side-stream filtration systems, and deep basin tower construction should be discouraged, unless the system is equipped with highly efficient filters to deal with suspended solids build-up. In addition to the accumulation of suspended solids, the user must consider the influence of suspended solids on the proliferation of micro-organisms. In addition to suspended solids, process leaks and airborne contaminants can greatly influence the rate of microbial proliferation.

Many plants employ clarification practices to clean up the water and remove the suspended material prior to use. On the other hand, some plants are specifically designed to perform with high solids surface water. They do this with well-designed exchangers that incorporate good metallurgy that is relatively resistant to corrosion and erosion, high flow rates, and easily cleaned bundles, such as straight tube shell and tube designs with removable heads on both ends to facilitate mechanical and/or chemical cleaning and inspection. Some facilities that receive high solids surface water are equipped with systems such as Amertap, an on-line mechanical cleaning system incorporating recirculating sponge balls that have been surfaced with various abrasive materials, depending on the nature of the foulant.

Plants that receive water with rapidly varying chemistry can sometimes benefit from make-up pretreatment, such as partial softening, partial RO treatment, supplemental mineral feed, and make-up pH control. Especially in plants with rapidly varying make-up quality, the available water should be modeled using one of the advanced solubility predictive programs, such as Water Cycle, to predict the impact of the make-up variations on the performance of the system as make-up varies. In this way a chemical treatment protocol or possibly multiple protocols can be developed to deal with the make-up variation. Very small systems will usually find that by setting the blow-down at a rate that will accommodate worst case conditions, and then designing the treatment program around this set of conditions, that good results can be obtained with minimal automatic controls, and acceptable over-all cost. If the systems are large enough for the blow-down heat, water, and chemical savings to justify the extra cost, then advanced controllers, using PLCs and appropriate control algorithms, can be programmed to automatically change control ranges and chemical feed rates as make-up water quality changes.

System Water Chemistry Control parameters:

As mentioned earlier, in order to limit the build-up of dissolved solids in the system recirculating water, a method of controlling this process must be provided. In addition to the build-up of dissolved solids, other factors, such as pH and oxidant control will probably be required.

PH Control:

The selection of pH control range is, in my opinion, possibly the most important control factor, and one of the least clearly understood and misapplied areas of cooling water chemistry today. There is a misconception that the corrosion rate of mild steel is reduced in open aerated cooling water systems by increasing the pH control range in the cooling water. While this is certainly true at pH values below 5.0, and above 9.5, the range in between is where we usually operate, and therefore where the problem lies. The idea that corrosion rate is reduced as pH is increased within this range is potentially a dangerous one, responsible directly and indirectly for many program failures. A graph of pH value versus corrosion rate for mild steel at constant temperature and constant flow rate in the presence of excess oxygen demonstrates this clearly.

Fig 1: Effect of pH on Iron Corrosion rate in water

Within this range the rate of corrosion of mild steel is relatively unaffected by pH. The type of corrosion that occurs instead changes in response to increasing pH, while the rate is largely unaffected. Within the range in question, reducing the pH tends to promote more even general attack, with less deposition in place of corrosion products, while raising the pH within this range promotes deposition of corrosion products in place, with attendant pitting under deposits. This tends to fix anodic areas of the metal in place, and to reduce the relative size of the anodic surface, while the corrosion potential remains unchanged. This mechanism tends to increase the pitting tendency. In addition to in-place deposition of corrosion products, higher pH values often contribute to greater potential for scale formation in the case of many sparingly soluble salts. It is this tendency that I believe is responsible for the assumption that changes in pH within this range directly reduces corrosion rates.

Three factors have combined to promote this misconception, the first being the relatively weak corrosion inhibiting properties of the modern “green” inhibitors, the second being a desire to eliminate the use of acid, especially in smaller systems, due to safety considerations and to concerns over control variability, and the third being a trend toward neutral to above neutral discharge limits with respect to pH. The implementation of higher pH limits than were used in the past has been made possible by the development of more effective deposit control programs employing the organo-phosphates, organic copper corrosion inhibitors, surfactants, and by the introduction of increasingly specialized and more effective low molecular weight dispersant polymers.
Cooling Tower Resources Inc.
MANUFACTURING, FABRICATION & SUPPLY

CTR...the Company you can count on!

A full service cooling tower supply company with two convenient locations to meet your needs for new construction and aftermarket repair materials. Our Northern California fabrication plant stocks over a half-million board feet of structural Redwood, Douglas fir, and plywood with CCA treat facilities. The Channelview Texas location stocks treated lumber & plywood, hardware, fiberglass, and a full line of construction products to meet the needs of the aftermarket and repair customers.

Prefabricated Parts for Quick Response
Pressure Treated Redwood Fan Decking
Over 500,000 BF Structural Lumber & Plywood

High speed boring and trimming facilities
24-hour response on fabricated repair parts
Full line of hardware, caulking, fiberglass, & nails

Two Service Locations offer fast response, and the convenience of a One Stop Shop, makes CTR the natural choice for your cooling tower needs.

Visit Our Web Site at www.cooltower.com

Houston Office
15653 N. Brentwood
Channelview, TX 77530
281 452-1510 Voice
281 452-1210 Fax
ctrhouston@cooltower.com

Corporate Office
P.O Box 159
1470 Grove Street
Healdsburg, CA 95448
1-800-245-8158
707-433-3900 Voice
707-431-8900 Fax
ctr@cooltower.com
While depending on increased pH to help control corrosion may work in small, very low temperature, low heat flux systems, where cycles of concentration are not maximized, and where metallurgy is confined to more corrosion resistant alloys, it is easy to delude yourself into thinking that you have provided good corrosion and deposition control, and then find that the hotter surfaces are suffering deposition, while the cooler areas are experiencing higher corrosion rates, or more pitting than expected. Where the problem becomes severe is in larger, higher temperature, lower flow, and higher skin temperature process systems, as well as when someone decides to tighten things up and to minimize water consumption, maximize cycles of concentration, and minimize inhibitor discharge at the same time.

This becomes especially acute when combined with “enhanced” heat transfer devices that employ thinner heat transfer surfaces, especially those designed with fins and grooves, which make great places for deposition of alluvial materials, such as corrosion products, airborne suspended solids, high make-up suspended solids, precipitates of scale forming minerals in the bulk water, and suspended materials leaked from process. Microbial sessile and planktonic contributions to deposition further exacerbate the process. The thinner heat transfer surfaces often mean higher skin temperatures at the same time. We see this situation potentially developing now with the introduction of some of the “enhanced” chillers being offered in the HVAC industry.

In addition another misconception has been propagated throughout the industry. That is the idea that the older expectations for corrosion rates were too restrictive. I frequently see performance specifications that call for over-all corrosion rates of 2 mpy, or higher on mild steel. While this is fine so long as there is no pitting, such is not usually the case, especially at lower water velocities and at higher temperatures and pH values. To add insult to injury, I see many applications where these compromises are implemented in systems where high suspended solids make-up is employed, especially in the presence of exchanger designs that promote deposition, such as plate and frame exchangers or low velocity shell and tube exchangers with the open cooling water on the shell side, without adequate provisions for mechanical cleaning of the exchangers.

In addition to promoting general corrosion as opposed to pitting, the lower pH control limits will generally minimize deposition by minimizing scale formation, with calcium sulfate being a notable exception. The inclusion of zinc in the inhibitor formulation will further help to reduce overall corrosion rates and to minimize pitting. Some of the organic inhibitor ingredients actually partially sequester zinc, subsequently widening its application as an inhibitor ingredient, and stabilizing it in the presence of higher pH values, as well as process leaks that may tend to promote the deposition of zinc, such as “sour” sulfur bearing process materials. While the impact of zinc on the environment must be considered, many systems discharge their blow-down into municipal and/or industrial waste water treatment systems that are operated to dilute and/or to remove such contaminants down to a level that is safe for discharge to a receiving stream. Zinc is in fact a component of many municipal potable water corrosion control programs.

Virtually all of the phosphate and organo-phosphorous bearing inhibitors will provide lower and more uniform corrosion at lower pH, rather than higher, within the range normally encountered in open recirculating systems. Another benefit to pH control in the lower end of the recirculating cooling water system range is that the less expensive chlorine bearing oxidants work better, and frequently this precludes the need for the more expensive bromine, ozone, and chlorine dioxide chemistries that tend to work better than chlorine based materials at the higher end of the pH range.

Most of the “all organic” formulations actually provide relatively poor actual corrosion inhibition and protection in a classical sense at any point within the normal pH range. So many practitioners recommend elevated pH to try to overcome corrosion of mild steel by precipitating a very thin layer of calcium carbonate on the steel surfaces. While this can be made to work relatively well in high velocity, low heat flux, low temperature systems, especially in those with copper or copper alloy heat transfer surfaces, it leaves much to be desired in hotter systems, where temperature differences force un-even scale deposition, resulting in either excessive scale on the hot surfaces, or excessive corrosion on the cold end.

In my opinion, a better approach in the more severe systems is probably the use of metaphosphate at relatively high levels, with zinc if possible, combined with lower pH control ranges, sufficient organic copper inhibitor to largely overcome any tendency toward copper alloy corrosion, and the use of specific low molecular weight dispersants that work well on stabilizing calcium phosphate and any other sparingly soluble salt present in concentrations high enough to exacerbate their tendency to precipitate under the prevailing physical and chemical conditions present. Depending on the rate of reversion of the metaphosphate, some orthophosphate addition may be desirable, as well, especially in the less challenging lower heat flux segment of the process cooling water market.

If this approach is used, the operator should use oxidants on a low level continuous basis carefully to control microbial growth without degrading the inhibitor ingredients (phosphonates, organic copper inhibitors, and phosphates) due to excessive oxidant feed. If necessary, the oxidants can be supplemented with periodic slug addition of higher levels of specific non-oxidizing microbicides.

**Cycles of Concentration:**

The second most critical control parameter in most open cooling systems is the control of the degree of concentration of dissolved solids permitted as a consequence of system blow-down or bleed-off rate. The cooling tower cools primarily due to evaporation of a portion of the recirculating water. Because the water that is evaporated leaves the system primarily as pure water vapor and the dissolved and suspended solids that the water originally contained are left in the remaining system water, this water becomes progressively more concentrated with respect to its original dissolved and suspended constituents. If this process is left un-controlled the build-up of solids will eventually cause one or more sparingly soluble salts to exceed their individual solubility product s and to precipitate. When this occurs, these precipitated solids tend to form on either the hottest or the coldest system surfaces, depending on how temperature affects the solubility of the specific salt. While most limited solubility compounds exhibit inversely proportional solubility with respect to temperature (higher temperature decreases solubility), a few exhibit direct solubility (lower temperature decreases solubility). Some silica deposits are examples of direct solubility. These specific materials will be found typically on cooling tower fill.
ZINCobre INGENIERÍA, S.L.U.

ZACT® ZINCobre Atmospheric Cooling Towers

More than 50 ZACT® in the world

If your plant requires new cooling towers for process fluid with solids in suspension, you will find a good support in Zincobre.
We can help you.

If you already have electrolytic cooling towers, but you wish to increase their efficiency, we can help as well.

Our solutions are carefully studied to make the most of your existing installation and minimize your investment to provide the lowest cost solution while increasing performance.

Zincobre focuses on providing the best overall project value.

www.zincobre.com

Fernando del Santo, 28-30, 1ª, Oficina 2
33204 Gijón - Asturias - España

T: +34 984 29 29 00
F: +34 984 29 39 00
E-mail: zincobre@zincobre.es

Zincobre’s Contact in Shanghai, China
Address: 3BF, Park Place
No. 1631 Nanjing Road West, Shanghai 200040.
P.R. China
Tel: +86-21-6137 3206
Fax: +86-21-6137 3210
E-mail: zincobre@zincobre.es
For this reason, the gradual concentration of solids by evaporation is at some point limited and controlled by removing a pre-determined amount of the concentrated cooling water by blow down, and by replacing its contribution to system volume with fresh make-up water. The blow-down rate is then varied to achieve a constant level of the most critical dissolved solids as thermal load and make-up water composition vary. The rate of blow down is controlled manually, based on operator control testing, or automatically, based on control valve response to either continuous conductivity level, or to the results of automatic analysis of another appropriate system control parameter, such as iron, silica, and/or calcium of magnesium.

The degree of desired system water concentration, or “cycles of concentration” is selected by comparing the most critical parameter with respect to precipitation of its most insoluble salt. This process can be conducted empirically, based on the operator’s knowledge of the most critical parameter given the make-up water chemistry and the system operating characteristics. Alternatively, if multiple control parameters are likely to limit solubility as operating conditions and water chemistry changes over time, then the availability of very easy-to-use software permits the use of a computer to make this selection based on solubility predictions generated by the software. Of the available alternatives, Water Cycle is the best known and the most widely used program, and the developer of this software is speaking during this same meeting that we are currently attending.

The determination of the desired “cycles” is further refined based on the cost and availability of make-up water, the treatment chemistry being employed, local regulations governing discharge, energy cost, the time-stability of make-up water chemistry, the criticality of system operating conditions, the cost of suffering poor control, the availability of advanced pretreatment equipment to provide optimum make-up water chemistry, and the amount of operator time, or the availability and sophistication of automatic control system equipment to be devoted to system chemistry monitoring and control testing.

We should remember that while it is technically possible to achieve very high cycles of concentration in many systems under very specific circumstances, there is a point of diminishing returns from the stand point of water, chemical, and energy savings, as cycles are pushed progressively higher. While these savings are a linear function of blow down volume reduction, the reduction in blow down volume itself is a logarithmic function of recirculation rate. In most systems, there is little point in driving cycles higher than about 10, as the blow down savings diminishes very rapidly beyond this point. The savings due to blow down reduction can be greatly exceeded by the costs of suffering poor control if unexpected changes in system chemistry result from changes in make-up composition, process temperatures or flow rates, pH control swings due to control system malfunction, or sudden changes in blow down rate due to cycle control deviation or failure. This is especially true in smaller systems, where control sophistication and operator attention may be minimized due to first cost or to labor cost considerations. In addition, the system holding time index increases very rapidly as cycles increase, greatly exacerbating fouling problems due to suspended solids accumulation and to degradation of treatment chemicals and subsequent deposition of the degradation products.

The purpose of this paper is not to answer all of the questions that will arise as a result of the discussion, but rather it is to provoke thought and discussion, and to help the reader to understand the complexity of the process of selecting, applying, and optimizing a control chemistry program for each cooling tower system, based on a knowledge of the factors that must be considered in order to arrive at the best answer. Unless plant personnel are well versed in this process, it is very important that they choose a water treatment professional that has this experience, and also has the time available to assist the plant in the development, proper application, and on-going control of the program.

Corrosion Control:
Corrosion control is normally accomplished by optimizing those non-chemical factors (flow, temperature, metallurgy, etc.) that influence the reaction, and by controlling the pH and dissolved solids concentration and the oxidation potential in the cooling water to the proper range, and by the addition of specific chemical corrosion inhibitors. The chemical corrosion inhibitors consist of soluble compounds that are added to minimize the corrosion reaction. They do this by acting at either the anode, the cathode, or at both the anode and cathode. Inhibitors are thus broadly classified as anodic, cathodic, or mixed anodic and cathodic inhibitors.

Anodic inhibitors function by decreasing the rate of transference of metal ions into solution. They generally tend to decrease the area of the anodic surface. While this mechanism results in a reduction of the over-all rate of reaction, any remaining attack is concentrated over the remaining anodic surface. For this reason, the anodic inhibitors result in an increase in the intensity of attack, or the tendency to result in severe pitting, unless the over-all corrosion process is completely stifled.

Cathodic inhibitors reduce corrosion by interfering with any of the steps of the oxygen reduction reaction, which is the primary process occurring at the cathode. Cathodic inhibitors do not affect the relative size of the cathode or anode, and thus decrease both the rate and the intensity of the corrosion reaction. Because of these differences in mechanism of corrosion control anodic inhibitors are sometimes referred to as “dangerous inhibitors”, while cathodic inhibitors are referred to as “safe inhibitors”. In other words, an under-feed of anodic inhibitor can result in progressively more severe pitting, while an under-feed of cathodic inhibitor does not increase pitting.

In practice, both types of inhibitors are normally combined into the inhibitor program to provide corrosion control at both the anode and the cathode.

Scale Control:
Scale control resulting from the feed of scale inhibitors is accomplished by one of three primary mechanisms:

• “Solubility Product Modification”, where the scale forming species is maintained in a completely soluble state as it passes through the system.
Experience the expertise in Global Cooling Technologies from

PALTECH™

More to it than meets the eye...
The proverb stands tall in its meaning when it comes to PALTECH Cooling Towers. Whenever huge installations are required, exceptional technical knowledge and capability to deliver as per commitment is of prime importance, a challenge that PALTECH has always met and continues to meet.

It's another matter that Cooling Tower featured above with an installed capacity of 150,000 GPM can only be viewed partially...

MANUFACTURES
OF COOLING
TOWERS IN:
• Pultruded FRP
• Steel
• Concrete
• FRP
• Timber

OUR EXISTING
CLIENTS IN:
• Europe
• Middle East
• North Africa
• South Africa
• South Asia
• Asia

We also manufacture all the components for Cooling Towers

BEST QUALITY | COMPETITIVE PRICE | FAST DELIVERY

PULTRUDED | STEEL | WOODEN | GEARBOXES | FRP FANS

Paltech Cooling towers & equipments ltd.
B-604, Sushant Lok, Phase-I, Gurgaon Haryana-122002, India
Email: patech@paltech.in, patech@paltech.net.in, Web: www.paltech.in
22 YEARS OF EXCELLENCE..... REACHING OUT GLOBALLY
Microbial Control:
Control of the growth of undesirable micro-organisms is typically accomplished through the addition of microbicides, or chemicals that retard or prevent the growth of the organisms. These products are classified into two different groups, designated as “oxidizing microbicides” and “non-oxidizing microbicides”. The oxidizing materials consist of oxidizing agents such as chlorine. These products function by “burning” the organisms, or causing the rupturing of the cell wall and lysing (the death of a cell by breaking of the cellular membrane, causing the contents to spill out) of its contents. The non-oxidizing products contain specific agents that are toxic to the organism, and which retard its growth and reproduction.

The oxidants typically work well at very low concentrations. They must be carefully controlled because they are non-selective, and they will oxidize beneficial chemicals in the system water, as well as system materials of construction. For these reasons, oxidants are typically fed to achieve and maintain a continuous low level of active ingredient sufficient to retard the organisms, but at concentrations low enough to avoid deterioration of beneficial chemicals as well as system components. Typically organisms do not develop any resistance to oxidants, so it is not necessary to alternate oxidants. Some organisms can combat the action of the oxidants by generating slime masses, or accumulations of metabolic products that provide a physical barrier to the oxidants. In order to prevent this, the oxidant can be periodically slug fed at a higher temporary use rate, or the use of the oxidant can be combined with periodic non-oxidizer slug based use, with or without bio-dispersants, to defeat these mechanisms.

Each oxidant shows relative benefits over the others, depending on the system operation and chemistry. In some cases more than one specific oxidant is fed at the same time. Many of the oxidants are available as inorganic as well as organic products. The choice of specific chemistry, as well as the physical form and concentration is made based on cost, effectiveness, method of application selected, and safety considerations. In general, the oxidants can be fed continuously or as slug or shock fed materials. The susceptibility of many of the organic inhibitor ingredients to destruction by oxidants generally limits their application to continuous addition, under carefully controlled conditions, where the level of oxidant present, as well as other chemistry parameters is carefully controlled to prevent destruction or deactivation of these key ingredients.

The non-oxidizing products are generally very specific organic toxicants that function by interfering with cell function by permeating across the cell wall and interfering with the cell’s metabolic processes without oxidizing the cell directly. These compounds usually require a much higher level of active ingredient for optimum function, and they are generally less deleterious to both inhibitor components as well as system materials of construction, so they are periodically slug or shock fed on some pre-determined frequency, under specific system chemistry requirements.

The treatment is typically repeated at a frequency that will prevent excessive growth of the organism between treatments. Because non-oxidizers are typically fed at levels that do not result in a complete kill of all organisms, the organisms can gradually acclimate to the presence of the toxicant, and they can develop resistance to it. For this reason, more than one oxidant is normally fed on a rotating slug basis, if only non-oxidizers are being used.

In most systems specific chemicals are fed to control the proliferation of deleterious micro-organisms, including bacterial, algae, fungi, slime forming organisms, and molds. These organisms exist as stationary as well as free floating populations. In addition to plugging and deposition in the system due to accumulation of the organisms, some species can directly exacerbate corrosion of most common metals due to secretion of acidic materials, including some sulfur bearing metabolic products. Other species can attack and metabolize components of wood used in construction of tower components. Still other organisms are capable of directly metabolizing and deactivating treatment chemical components including the phosphates, organo-phosphates, copper inhibitors, and microbicides.

In addition to direct chemical action on the system components, a host of organisms are capable of entering into the formation of deposits, which accumulate on the surface of system metals and other components, and aggravate the corrosion and deterioration mechanisms by reducing water flow, increasing temperature by retarding heat transfer, and by reducing the oxygen concentration at the metal surface, causing the formation of anodic areas with respect to the bulk of the metal surface.

Because of cost, toxicity, and system component deterioration considerations, microbicides, oxidizing, or non-oxidizing, are usually fed based on the results of specific chemical, and/or physical tests, as well as based on system volume, make-up water rate, and system holding time index.

Regardless of which materials are selected, they are generally applied based on their biological control performance. This is typically measured by collecting samples of system water, and samples of any materials accumulating on system surfaces, and by measuring the concentration of organisms present using serial dilution and specific plate count methods. In addition direct visual examination of equipment, as well as heat transfer measurements are normally used to confirm performance. The use of corrosion coupons and heat transfer test devices often provides additional data related to the performance of microbicides with respect to their impact on these aspects of the program.

Because the ingredients of these products are toxic, their use is strictly regulated by various agencies such as state and federal environmental protection agencies, various local agencies, the USDA, the FDA, and by other agencies depending on industry and location. Before permitting the presence of these materials on sites under their supervision, the operator should insure that all products brought in by the vendor, or purchased from the vendor, comply with all appropriate regulations regarding registration, labeling, storage, handling, and application. The vendor should provide appropriate...
INNOVEK COOLING TOWERS

- CROSS FLOW / COUNTER FLOW
- FRP/HDGS/WOOD/CONCRETE STRUCTURE
- DESIGN NEW AND UPGRADE OLD UNIT
- TURNKEY CONTRACT
- SERVICE/REPAIR
- SUPPLY PARTS

WATER TREATMENT PLANT

- CLARIFICATION SYSTEM
- AUTOMATIC BACK WASH SAND FILTER
- DEMINERALIZATION SYSTEM
- REVERSE OSMOSIS SYSTEM
- EDI AND IONEXCHANGE
- SOFTENER
- FILTRATION
- MOBILE WATER PLANT

WWW.INNOVEK.CO.TH  TEL: +6638-021634  FAX: +6638021635  EMAIL: sales@innovek.co.th
handling, application, and safety training for all chemicals involved in the treatment program. In some states, personnel who actually apply the biocides must be licensed by the state, and they must receive specific application, safety, and environmental training before they are allowed to use these products. California is an example of such state regulation.

One specific organism, legionella sp., is capable of causing human respiratory disease. While it is unusual to find this organism in concentrations high enough to cause disease in most cooling tower systems, the disease can be devastating in susceptible individuals, or in individuals who do not receive proper diagnosis and treatment. For this reason it is good policy to implement a routine testing program to insure that legionella does not become a problem in your plant. The presence of this organism, in concentrations high enough to be troublesome, is generally the result of improper system water treatment combined with inadequate equipment maintenance and cleaning.

This organism is not limited to cooling towers, but can be present in all kinds of water handling systems, such as cooling ponds, evaporative condensers, decorative pools and fountains, domestic potable water systems, humidifiers, etc. Any system where the water is broken up into droplets small enough to be suspended in the ambient air and inhaled by people is a concern, and a proper program should be implemented. There are many good papers on the subject, and there are proven treatment and maintenance programs that, combined with a proper testing protocol, can protect personnel subject to exposure. This is a relatively inexpensive and straightforward control program that provides a lot of peace of mind for management, personnel, and the public.

Sludge and Silt Control:
Materials from many different sources (scrubbed from the air, present as suspended solids in the make-up, or contributed from process contamination, or as the result of the growth of micro-organisms) can accumulate in the system into masses of soft deposits. These materials tend to settle out in low velocity regions of the circulating system. Aggravated corrosion and microbial growth can occur under these deposits, and they can interfere with heat transfer. In addition proper equipment design criteria and to the use of mechanical means to minimize the accumulation of these deposits, specific deposit inhibitors can be fed. These are typically large polymeric organic molecules, or combinations of such materials, that can behave as either dispersants or as flocculants. Such properties are modified by selection of specific molecular weight materials, as well as by selection and incorporation of various functional groups. The dispersants function by causing the suspended solids to form very small particles with specific surface electrical charges that result in suspension of the particles back into the bulk water, where they can be carried out of the system. The flocculants have the opposite effect. They cause the suspended solids to accumulate into larger particles with lower over-all particle density that are more readily moved out of undesirable locations by the force of the flowing recirculating water.

In addition to the dispersants and the flocculants, surfactants are sometimes used in cooling water systems to aid in the break-up and penetration of slime masses generated by organisms, and organic deposits due to process leaks. The surfactants also function as “oil dispersants”, and help remove oils from system surfaces and cause it to disperse in the cooling water until it can be removed by blow-down or by mechanical means within the system (filters, floatation units, etc.). Surfactants are typically used at very low treatment levels, and they are typically slug fed as needed. In some cases they are fed continuously along with the other inhibitor ingredients.

Foam Control:
Cooling water systems frequently are prone to the generation of unacceptable foaming, caused by process contamination, contamination from the ambient air, and foam due to the oxidation of organics by oxidizing microbicides, or foam generated due to over-feed of surfactants and some microbicides. Excessive foam blanketing can interfere with heat transfer, and foam discharged from the system by the tower fans can cause contamination of items within the drift range of the tower. Such airborne foam can result in problems such as paint spotting, etc. Classes of chemicals known as antifoams are sometimes used to control foaming tendency. These chemicals are typically chosen from certain oils, and water soluble organic silicone compounds. Antifoams are typically slug fed at very low doses as needed to control foaming.

Treatment Chemistry Selection:
There are many alternative treatment chemistries available. The choice of which program to use, and how best to apply it, is based on many factors. A brief discussion of the most commonly employed inhibitor ingredients is now in order. Again, my purpose is not to provide exhaustive details in this paper, but to help guide individuals in determining what questions to ask to begin the process of selecting the best program for their individual circumstances.

Phosphates:
Specific inorganic phosphorous compounds exhibit desirable scale inhibition, as well as corrosion inhibition properties. They provide corrosion inhibition on a variety of metals, including mild steel. Of these inorganic phosphorus bearing compounds, orthophosphate and meta-phosphate enjoy the widest applicability.

These two compounds are polymeric oxides of phosphate with different oxidation states, different molecular weights, and differing oxygen to phosphorous ratios. Ortho phosphate functions as a corrosion inhibitor primarily by functioning at the anode. Metaphosphate, or polyphosphate, works at the cathode.

Phosphates:
Specific inorganic phosphorous compounds exhibit desirable scale inhibition, as well as corrosion inhibition properties. They provide corrosion inhibition on a variety of metals, including mild steel. Of these inorganic phosphorus bearing compounds, orthophosphate and meta-phosphate enjoy the widest applicability.

These two compounds are polymeric oxides of phosphate with different oxidation states, different molecular weights, and differing oxygen to phosphorous ratios. Ortho phosphate functions as a corrosion inhibitor primarily by functioning at the anode. Metaphosphate, or polyphosphate, works at the cathode.

Sodium Hexametaphosphate

For this reason, orthophosphate is classified as an anodic inhibitor, while metaphosphate is classified as a cathodic inhibitor. Metaphosphate functions as both a corrosion and as a “threshold stabilization” type scale inhibitor, while orthophosphate does not inhibit scale formation. Orthophosphate, in fact, can combine with calcium, iron, and certain other cations to form scales which exacerbate the problem. This tendency, combined with the pronounced tendency of metaphosphate to revert to orthophosphate, proved to be the primary
India's No.1...FRP Cooling Tower!

With Over 16,000 Satisfied Customers

India's only Cooling Tower with CTI (USA) certification for ‘A-SERIES’ Towers.

15000TR (Hyderabad)
3000TR (Bangalore Airport)
4000TR (Gurgaon)
3200TR (Mumbai)

Upto 1000 TR available in single cell.

Introducing 100% Non-corrosive FRP Towers.

Also available Non-CTI ‘AL & TM’ Series Cooling Towers.

Approved by “Indian Green Building Council” for Green Buildings.

Advance GRP Cooling Towers Pvt. Ltd.
405, ‘Span Centre’, R.K. Mission Marg. Santa Cruz (W), Mumbai - 400054. INDIA
Tel: 2600 1067/68 Fax: 2630 0303. E-mail: sales@advance2020.com, www.frpcoolingtowers.com
Branch Offices: • Bangalore: 0990521598 • Delhi: 09953658971 • Chennai: 09445155645

Visit us at AHR EXPO Stall no. N 5112, Jan 31st 2010 to Feb 2nd 2011
Las Vegas Convention Center, Las Vegas, Nevada.
limitation on the usefulness of the phosphates in large, high volume, low flow, high temperature, industrial cooling systems prior to the development of the organo-phosphates and the modern dispersants. The performance of phosphate based inhibitors can be enhanced by the addition of other ingredients, such as chromate, zinc, silicate, molybdate, and one or more of the organo-phosphates. When copper alloys are present, the usefulness of the phosphates can be extended, and the useful pH range broadened, by the addition of one of the available organic copper inhibitors.

Modern polyphosphate based programs, supplemented with organo-phosphates, specific dispersant polymers, and organic copper corrosion inhibitors, enjoy wide acceptance and perform very well in refinery open recirculating cooling water systems, as well as in other very critical high temperature, low flow, high holding time index systems in other industries.

Organo-phosphates:

Many different organic molecules containing phosphorous are of significant benefit as scale and corrosion inhibitors. Of these, the most widely employed in water treatment are ATMP (amino trimethylene phosphonate), HEDP (hydroxyethylene diphosphonate), and PBTC (phosphonobutane tricarboxylic acid).

Dispersants:

Specific low molecular weight organic polymers can be added to water to alter the surface charges of finely divided suspended solids particles and cause them to repel each other, or to disperse themselves and to re-suspend into the system water. This approach can be used to help remove finely divided solids that have settled out of suspension and contributed to the formation of soft sludge in the system. It can also be used to disperse particles as they precipitate out of solution, and to keep them suspended until they are removed from the system by blow-down. This class of compounds also has the ability to interfere with orderly crystal growth, and to minimize deposit formation by a process known as “crystal modification”. Some of these polymers can limit crystal growth to a size where inter-particle charge density and repulsive forces prevent precipitation, a process known as “threshold stabilization”.

The development of very specific dispersant products, capable of selectively dispersing specific precipitants, has greatly expanded the role of cooling water treatment in recent years, and allows us to safely exceed solubility products that were inviolate just a few years ago. This is the technology that I mentioned earlier that allows the use of higher pH limits in open cooling water systems than were previously employed.

The end results of this technology can be dramatic and quite beneficial, but its use must be carefully controlled using proper chemistry selection, close observation, and proper control limits. Improperly selected and applied dispersants can result in dramatic scale formation very quickly.

Flocculants:

Specific high molecular weight organic polymers, such as the polyacrylamides, cause suspended solids, oils, and grease present in a given water to “floculate”, or to agglomerate into larger particles of lower density and altered surface charge than the original suspended material. These larger particles, having a much greater individual particle surface area combined with a lower particle density, can frequently be subsequently removed from the system after such treatment, by the force of any water flow present. This technology has been used for many years to successfully remove mud and silt from tankage, from the bilges of vessels, and from system piping and heat transfer equipment, and it can be considered anywhere that there is enough water flow to suspend the particles so formed and sweep them from the system. This same sort of agglomeration is also used in waste water treatment to remove suspended solids, oil, and grease, using clarifiers and or floatation units.

Molybdenum:

Molybdenum is often used supplementally as an additional ingredient in corrosion inhibitor formulations. I have worked with a wide range of open and closed cooling water systems using molybdenum, and I am sorry to report that I have not seen some of the very good results reported by others. When you consider that molybdenum is a strongly anodic inhibitor, similar in function, but less effective and more expensive than chromium, it is not too hard to see why molybdenum has not lived up to the early promises reported in the literature. In order for molybdenum to function effectively it must be used at high concentrations. Because of its expense, precluding its use at high levels, it is rapidly being relegated to the role of an analytical tracer. Despite these comments, molybdate is currently being widely used, especially in the HVAC industry, where it can
FIBERGLASS
The Smart Choice for Cooling Towers!

No Rotting or Decay!

Installation Savings!

Lightweight, Strong & Durable!

Ideal Products for Cooling Towers

Dimensional FRP Wood Alternatives

DURASHIELD HC® Hollow Core Building Panels

DURAGRID® R-8300 Pultruded Grating

Our Design Manual is now ONLINE! Visit now to sign up for 24-hour access to the most up-to-date design information available!

STRONGWELL
The World’s Largest Supplier of Solutions for the Cooling Tower Industry!

400 Commonwealth Avenue, Bristol, VA 24201
(276) 645-8000 • Fax (276) 645-8132
info@strongwell.com • www.strongwell.com

www.strongwell.com/designmanual
be effective in combination with zinc, phosphates, and other ingredients in these smaller systems with relatively mild operating conditions, relatively high water velocity and more corrosion resistant alloys, minimal water volume and holding times, and no process contamination. Molybdenum may also have some benefit in the control of pitting, but this is questionable in light of relatively poor performance in a growing number of systems.

I much prefer to see the active ingredients of the inhibitor being used for control testing, rather than a tracer with no other function, as I have seen many programs fail because the tracer, for one reason or another, did not accurately measure the level of the actual ingredients doing the work.

**Zinc:**
Zinc is a very beneficial cathodic corrosion inhibitor. It can be incorporated into a finished product with a variety of inorganic and organic compounds to form very effective mixed cathodic/anodic corrosion inhibitors.

**Specific Organic Copper Corrosion Inhibitors:**
Another area of cooling water chemistry that is frequently misapplied is the use of specific organic copper corrosion inhibitors. These organic inhibitors (benzotriazole, mercaptobenzothiazole, and tolyltriazole, or their close cousins) are required any time that the organo-phosphorus or phosphorous based inhibitors are being applied, especially without zinc, to mild steel systems containing copper alloy components in the cooling water loop. The organo-phosphorous compounds are not copper or copper alloy corrosion inhibitors. In fact, they can be corrosion accelerators of these metals, and can result in high steel corrosion rates by increasing the background levels of soluble copper with resultant plating of copper onto steel surfaces, with attendant pitting of the steel. Several of these compounds are employed in bottle washing and other chemical cleaning applications as copper sequesterants. These materials should be continuously fed to achieve control ranges of 2 to 8 ppm of the active organic inhibitor salt in open recirculating systems in order to minimize copper alloy corrosion, and the attendant plating of copper on mild steel surfaces, which will aggravate pitting of the steel.

These products are typically under-fed due to cost and solubility issues. The amount of copper inhibitor used should be verified with frequent analysis of available inhibitor and feed rate correlation, and the results should be confirmed with both copper, copper alloy, and mild steel corrosion coupons to verify performance and to adjust inhibitor feed and control. The feed of organic copper inhibitors should be carefully controlled and the results should be verified with coupon and analytical testing, especially where oxidizing biocides, such as chlorine or bromine are being fed. These oxidants, if not carefully fed and controlled, will oxidize and destroy the copper inhibitors, and they can promote chlorine addition to some of the organic molecules, which can result in reduced corrosion inhibition efficacy and in odor complaints because of the odor associated with the chlorinated molecule.

**Microbicides:**
As discussed earlier, a variety of different oxidants are used in cooling water systems to control objectionable organisms. Typically used materials include chlorine, bromine, hydrogen peroxide, peracetic acid, perborates, ozone, and chlorine dioxide. Non-oxidizing products include materials such as the quaternary amines, glutaraldehyde, dibromonitropropionamide, isothenazolin, methylene bisthiocyanate, 2 hydroxypropyl methanethiosulfonate, dimethylthio carbamate, oxydiethylene (alkyl dimethyl ammonium chloride),

**Surfactants:**
A variety of specific organic surface active molecules are frequently applied to cooling tower systems to disperse oils and biological slime masses, and to enhance the penetration of microbicides and inhibitors into deposit accumulations, allowing the needed ingredients of the treatment chemicals to reach all areas of accumulated deposits, as well as the surfaces of system components. These materials differ with respect to charge, and foaming tendency, as well as in their relative penetrating power. Selection of the proper surfactant and optimization of its feed can reduce over-all treatment costs, and improve performance of both microbicides and inhibitors. Surfactants such as the non-ionic octylphenol ethoxylates should be strongly considered any time the presence of oils in the cooling water, due to either process leaks or transference from ambient air is complicating program performance. Biodispersants such as the anionic lignosulfonates and the newer, more effective ethylene oxide/propylene oxide copolymers can very effectively be used to disperse slime masses, allowing the microbicides to achieve more effective and less costly kills.

**Antifoams:**
These organic materials are frequently applied to reduce foaming tendency in cooling systems. Foaming can be exacerbated due to process leaks, airborne contaminants, and due to the over-feed of surfactants as part of the treatment program. Several different types of materials, including some oils, can function as antifoams. Of these, the organic silicones are among the most effective, frequently providing good foam control at doses as low as 1 ppm based on system volume.

General comments about system chemistry components:
Many of the treatment chemicals available contain ingredients that carry electrically charged molecules. These ingredients may exhibit strongly anionic or cationic charge. Depending on the nature of such charges, and on the reaction with other soluble and insoluble materials present in the system water, a pronounced tendency to promote precipitation and deposit formation may exist. For this reason, these materials should be selected and their dosage proposed by individuals knowledgeable in the formulation and application of the products in order to minimize the tendency for deposit accumulation.

**Conclusion:**
This purpose of this paper is to help interested parties fully appreciate the complexity of the technology behind the implementation and maintenance of an operation, treatment, testing, monitoring, and data management program that will result in long term, trouble free, economical operation of their cooling systems, without suffering damage due to the common problems encountered due to water treatment and control problems. I hope that it will serve as the basis of further discussion and investigation, and that it will convince all interested parties that there is no one best treatment program for all cooling tower systems.
REXNORD® ADDAX® COMPOSITE COUPLINGS
HELPING COOLING TOWERS AND MAINTENANCE PERSONNEL KEEP THEIR COOL FOR MORE THAN 20 YEARS

In 1986, space age technology was introduced to the Cooling Tower Industry with the advent of the Addax® Composite Coupling. Being the first of its kind, the Addax® coupling was designed specifically for Cooling Tower applications. Since then, cooling tower coupling maintenance and corrosion problems have virtually been eliminated.

For more than 80 years, Rexnord has been designing and manufacturing couplings for almost every industrial application imaginable. We understand your need for easy-to-maintain and reliable components and are pleased to offer the Rexnord® Addax® Composite Coupling to fit the bill.

As the leader in the Cooling Tower Industry, Rexnord is committed to providing the absolute best quality and service available – anywhere. Check around the world, Addax® couplings deliver the best value for your Cooling Tower application.

Addax® Composite Couplings offer:

- Low Weight
- Excellent Corrosion Resistance
- High Misalignment Capacity
- Single Spans without intermediate support bearings
- No Fretting Corrosion
- Excellent Fatigue Life
- Shipments in days, not weeks – same day shipment is always available

Rexnord® Addax® Composite Couplings – recognized for twenty years as the industry leader and innovator.

Now that’s cool!

Call 866-REXNORD or your Rexnord Account Executive today to find out more about Rexnord® Addax® Composite Couplings!
The following approach was implemented for the cooling towers:

**ABSTRACT**

Concrete hyperbolic cooling towers built three to four decades back which have exposure to corrosion causing chlorides are susceptible to deterioration over a period of time. Such cooling towers are thin shell structures compared to their geometric proportions. As such, when a large area of concrete gets removed from such thin shell structures during the repair work, their structural integrity may be compromised when subjected to lateral wind loads due to hurricanes. For the repair work to proceed in an efficient and safe manner, concrete removal and replacement in the thin shell or veil of the cooling towers must follow certain protocols determined using some complex structural analytical techniques. This paper focuses on the veil repair.

**INTRODUCTION**

Finite element analyses of two natural draft cooling towers were conducted with the purpose of developing phasing plans for conducting surface repairs and installing cathodic protection systems while maintaining the towers in a safe and operational condition.

The towers were first analyzed in the as-designed state to assess the wind load capacity. The towers were then analyzed for the repair phase taking into consideration corrosion-induced concrete distress on the exterior surface of the tower veil.

Results of the capacity analysis indicated that the towers have limited reserve capacity for wind loads in the as-designed state per American Concrete Institute, Building Code Requirements for Structural Concrete, ACI 318-08 (1) and ASCE/SEI 7-05 “Minimum Design Loads for Buildings and Other Structures” (2) requirements. Analysis of the veil incorporating existing corrosion-induced concrete distress and future damage resulting from the concrete removal process for surface repairs revealed further reduction in structural capacity.

Based on these findings and information regarding tower access for repair implementation, constraints and staging sequences were provided for the non-hurricane season (December 1 – May 31) and the hurricane season (June 1 – November 30). Constraints for the hurricane season were, in general, more stringent than constraints for the non-hurricane season primarily because of the higher probability of hurricanes and the high stresses in the concrete and reinforcing bars caused by relatively high wind pressures associated with the hurricanes.

**Approach**

The following approach was implemented for the cooling towers:

- Review of available construction documents and condition assessment reports for the towers;
- Modeling the cooling tower columns, ring beam and veil using the finite element software package ANSYS (3);
- Determining gravity and code specified wind loads expected to act on the cooling towers;
- Determining the wind load capacity of the cooling towers in the as-designed state;
- Modeling and analyzing veil distress based on condition survey data.

**Background**

**Structure Description**

The two reinforced concrete towers analyzed were designed in 1980 and are identical in construction. The height of each cooling tower is approximately 137 m (450 ft) Each cooling tower veil is supported at the bottom by 40 pairs of precast diagonally oriented rectangular concrete columns. The inner diameter is approximately 104 m (340 ft) at the bottom of the veil, 31 m (100 ft) at the throat (location of the least veil diameter), and 34 m (110 ft) at the top of the veil. The thickness of the reinforced concrete veil wall is typically between 20 to 24 cm (8 to 9.5 in.) and increases to 79 cm (31 in.) and 99 cm (39 in.) at the top and bottom elevations of the veil, respectively. The veil is reinforced with interior and exterior mats of reinforcement in both the vertical and circumferential directions with a clear concrete cover of approximately 3.8 cm (1.5 in). Reinforcement used in the veil has a yield strength of 414 GPa (60,000 PSI). The veil consists of a cast-in-place reinforced concrete jump-form construction which originates from the concrete ring beam. Concrete placement lift height (i.e. vertical distance between successive construction joints) for the veil is about 1.8 m (6 ft). There are a total of 67 lifts in the veil (see Figure 1).

**Veil Condition Assessment**

A condition assessment of the towers was conducted before the towers were analyzed. The condition assessment covered a limited portion of each veil and included visual and delamination surveys by hammer sounding, as well as several photographs taken during the observation. The condition assessment did not include verification of the shape and verticality of the towers as detailed in the design drawings. Selected areas of the veil of each tower were accessed by swing stages. The current state of distress of the towers was modeled based on the following data:

- Information from the assessment report;
- Visual observations during a site visit.
WALTER P MOORE
ENGINEERING POSSIBILITIES

CONDITION ASSESSMENTS
CORROSION MITIGATION
NON-DESTRUCTIVE TESTING
RESTORATION AND REHABILITATION
STRUCTURAL EVALUATION
INSTRUMENTATION
PEER REVIEW

DILIP CHOUDHURI, P.E.
800.364.7300
DCHOUDHURI@WALTERPMOORE.COM

ATLANTA AUSTIN DALLAS EL PASO HOUSTON KANSAS CITY LAS VEGAS
LOS ANGELES ORLANDO SAN FRANCISCO TAMPA TULSA WASHINGTON, D.C.

WWW.WALTERPMOORE.COM
COOLING TOWER MODELING

Three-dimensional models of the cooling towers in the as-designed and distressed condition scenarios were created using the finite element analysis software package ANSYS. The original condition of the towers was modeled in accordance with design drawings. Possible imperfections due to construction errors such as variations in veil wall thickness, curvature, out of plumbness, diameter and height were not considered. Several models were created to evaluate various scenarios pertaining to distress due to delamination and spalling of concrete, and corrosion of reinforcement with each model assumed to represent both the tower units. Each model included the columns with associated foundation boundary conditions, the ring beam, and the veil. The foundation system was not included in the analytical models.

Modeling of distress to the external surface of the tower shells and columns was approached from a general rather than a localized sense. This was primarily because of the size and complex shape of the cooling towers and the nature and extent of distress, which included cracks on the exterior surface of the veil and some columns, delamination and spalling of concrete, and corrosion of exposed reinforcement. The approach taken was to model a distressed scenario that enveloped all the conditions mentioned above including possible construction related issues such as additional removal of sound concrete during repair, additional cracking of concrete, and unintentional cutting of reinforcing bars during repairs. Distress was modeled by reducing the thickness of the shell (from the exterior) in specific regions by selected amounts. Reduction in shell thickness was based on the nature of distress being modeled and was smeared around the circumference of the shell.

A combination of three-dimensional solid and beam elements were used to model the columns, ring beam, and veil. The columns were modeled with three-dimensional beam elements. The ring beam, veil, and cornice were modeled using three-dimensional solid elements. Solid elements were used in lieu of shell elements to model the veil primarily for the purpose of utilizing the reinforced concrete capability of ANSYS, which is only available for a particular type of solid element in the ANSYS element library. The solid element used in the analytical model had one solid material that represented concrete and up to three other materials that represented reinforcing steel. Reinforcing steel is defined by a volume ratio (i.e. ratio of reinforcing bar volume to total element volume), and two orientation angles, which are used to orient the longitudinal axis of the reinforcing bar in three-dimensional space. Boundary conditions between columns and the foundation were modeled as hinges based on evaluation of column/foundation connections shown in the construction drawings. Hinges are free to rotate but restrained against translation.

Representative images from the finite element models are shown in Figure 2 through Figure 4. Specific information on each of the two modeling scenarios is presented below.

As-Designed

For the as-designed model, geometry, dimensions, reinforcement and material properties of the columns, ring beam, and veil were obtained from the original construction drawings.

Distressed Condition

In the distressed-condition model, distress to the veil and columns, which were obtained from condition surveys, were analyzed separately. Material properties were the same as used in the as-designed model.

Veil Distress Model

The existing condition of the veil was modeled based on the findings from condition surveys of the cooling towers.

Information gathered from the condition surveys and visual observations of the towers revealed significant deterioration at the higher elevations of the veil (between lifts 42 and 67). Areas of distress were also identified in the lifts at the lower elevations of the veil (between lifts 1 and 4). Only distress on the exterior of the veil was considered in the analysis since no evidence of corrosion-induced deterioration on the interior of the cooling tower veil was found during the condition assessment of the towers.

Observed distress to the exterior surface of the veils of the cooling towers included cracks, concrete delamination, concrete spalls, and corrosion of exposed reinforcement. Although several scenarios were considered for modeling distress to the veil of the cooling towers, the scenario that incorporated all the conditions mentioned above is discussed in this paper. This model is a conservative estimate of the worst case of distress caused by both corrosion-induced deterioration and the repair methods expected to be employed.

Assumptions consistent with the distress identified in the condition surveys were incorporated into the finite element model. The model was divided into three regions of distress (Figure 5):

1. Region 1 - Lifts 1 through 4: Thickness of the shell was reduced by 9 cm (3.5 inches) and the exterior mat of steel eliminated to account for loss of concrete cover associated with delaminations and spalls, loss of reinforcing bar cross sectional area, bond of the exterior mat of reinforcement, and cracks in concrete.

2. Region 2 - Lifts 5 through 41: Thickness of concrete was reduced by 2.5 cm (1 inch) around the circumference of the model to account for scattered areas of unknown distress and for provision of a cathodic protection system that required concrete removal from the veil.

3. Region 3 - Lifts 42 through 67: Similar to Region 1, the thickness of the shell in this region was also reduced by 9 cm (3.5 inches) and the exterior mat of steel eliminated to account for loss of concrete cover associated with delaminations and spalls, loss of reinforcing bar cross sectional area and bond of the exterior mat of reinforcement, and cracks in concrete.

Column Distress Model

Observed distress to columns included cracks, concrete delamination, concrete spalls, and corrosion of reinforcement. Corrosion-induced distress was observed mainly at the corners of the columns. Distress to columns was modeled by modifying the as-designed cross section of columns (Figure 6) to approximate the observed deterioration. Although spalling and delamination were confined mainly to the corners of some columns (Figure 7), concrete cover on all sides and the corner steel were removed from the original section to simulate the distressed condition (Figure 8). This was done to account not only for the observed deterioration but also for
Yes, our construction teams have created a new record by building 18 natural draught (ND) cooling towers simultaneously for 9 power plant projects throughout India. No other cooling tower company has ever done this before.*

In fact, Paharpur has in recent years built more natural draught cooling towers – some as large as 175 m in height and 125 m in base diameter – than any other cooling tower company in the world. And, this new record is only further testimony to the trust large power plant owners and EPC contractors have placed in us over the years.

Paharpur has also compressed the time required to build ND towers by several months. At Hisar, Paharpur achieved a shell construction rate of 30 lifts / 45 m in a single month – yet another world record!*

So the next time you think cooling towers, whether natural or mechanical draught, you only have to think Paharpur…

*Source: Industry data.

Paharpur Cooling Towers Ltd. Paharpur House, 8/1/B Diamond Harbour Road, Kolkata - 700 027, INDIA
Phone : +91-33-4013 3000 • Fax : +91-33-2479 2188 • pctccu@paharpur.com

PAHARPUR USA, Inc. 165 S Union Blvd, Suite 750, Lakewood, CO 80228, USA
Phone : +1-303-989 7200 • Fax : +1-720-962 8400 • info@paharpurusa.com

Your Full-Service Cooling Tower Company
http://www.paharpur.com
any additional distress that may not have been observed during the survey, and the potential for unintentional removal of more concrete than necessary during repairs.

**COOLING TOWER ANALYSIS**

**Design Loads**

**Dead**

Typical unit weights of 24 kN/m³ (150 lb/ft³) and 77 kN/m³ (490 lb/ft³) were assumed for normal-weight concrete and steel, respectively. Once unit weights were specified, dead loads were automatically generated by the finite element software.

**Wind**

An important consideration of the analysis involved the determination of the wind pressure distribution. Wind-induced pressures acting on a natural-draft cooling tower are determined by the characteristics of the oncoming wind flow, the tower geometry, and the features of the tower surface such as the number and dimensions of the ribs to mitigate wind-induced vortices.

Through wind tunnel tests and full-scale measurements specific to natural-draft cooling towers, the pressure at any point of the tower can be defined by a height above ground and an angular coordinate. The wind pressure distribution at any height and angular coordinate of the natural-draft cooling towers was derived from complex formulas in the publications *Handbook of Structural Engineering* (4), *Wind Effects on Structures* (5), and supplemented with information from ASCE/SEI 7-05 “Minimum Design Loads for Buildings and Other Structures” (2). It is important to note that these pressure distributions are equivalent static pressures. In other words, the dynamic effects of wind are incorporated in the static pressure distributions. Figure 9 through Figure 11 present the wind pressure contours associated with a 100 mph 3-second gust wind speed for illustrative purposes.

A detailed discussion on this is given in *Analysis of Wind Load Capacity of Natural Draft Cooling Towers* (6).

At the time the towers were designed wind speeds were based on the fastest-mile format. The fastest-mile wind speed is defined as the highest sustained average wind speed based on the time required for a mile-long sample of air to pass a fixed point. Since the National Weather Service (NWS) has phased out measurement of fastest-mile wind speeds and replaced them with 3-second gust speeds, the wind pressure formula used in the analyses was based on the 3-second gust format. The 3-second gust wind speed is the peak gust associated with an averaging time of 3 seconds.

**Load Combinations**

Results from the analyses were compared with code-specified load and resistance factors (ACI 318-08/ASCE 7-05) by rewriting the demand capacity equations commonly used in design practice (Equations 1 and 2 below). The ultimate load combination of dead load and wind loads given in Equation 3 as specified in ACI 318-08/ASCE 7-05 by rewriting Results from the analyses were compared with code-specified load factors (ACI 318-08/ASCE 7-05) by rewriting

\[
\text{Dead Loads: } D = \text{Dead Load} \times f_d
\]

\[
\text{Wind Loads: } W = \text{Wind Load} \times f_w
\]

\[
\text{Required Strength} = 0.9D + 1.3W \quad \text{Equation 3}
\]

\[
\text{Nominal Capacity} = \frac{0.9D + 1.3W}{\phi} \quad \text{Equation 4}
\]

where

\[
D = \text{Dead Load}
\]

\[
W = \text{Wind Load}
\]

\[
\phi = \text{Strength Reduction Factor}
\]

A strength reduction factor of 0.9 was used in accordance with the ACI code referenced above. Equation 4 was used to compare the collapse load of the cooling tower model with code specified design loads. The basic wind speed specified in ASCE 7-05 for the geographic location of the cooling towers is 54 m/s (120 mph) using the 3-second gust wind measurement interval. This is the wind speed used in computing wind pressures to which load factors need to be applied when designing structures for wind in this region.

**Results**

The wind load capacity of the cooling towers in the as-designed condition was checked to assess reserve structural capacity, if any, which could be counted on during repair implementation. The analysis showed that the towers have limited reserve capacity per ACI 318-08 and ASCE 7-05 requirements as shown in Table 1. The column labeled “Expected Design” in the table shows the approximate wind speed at which an ultimate limit state event is expected to occur. This wind speed was determined by applying a load factor of 1.3 and a strength reduction factor of 0.9 as described in Equation 4 to pressures associated with the 54 m/s (120 mph) basic wind speed for the cooling towers studied using ASCE 7-05. The column labeled “ANSYS” shows the wind speed at which the as-designed finite element model of the cooling tower would undergo collapse.

<table>
<thead>
<tr>
<th>Wind Speed (3-second gust)</th>
<th>Expected Design</th>
<th>ANSYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>64 m/s (144 mph)</td>
<td>63 m/s (140 mph)</td>
<td></td>
</tr>
</tbody>
</table>

**Table 1. Comparison of wind load capacities**

In addition, models incorporating estimates of distress to the exterior surface of the veil and columns were analyzed to determine a lower bound wind load capacity. Results from the as-designed capacity check and the distressed-condition models were then used to formulate repair phasing plans with the objective of maintaining the towers in a safe and operational condition during repairs.

**Capacity Check and Veil Analyses**

Response of the finite element models to applied dead and wind loads was closely monitored to determine the load at which the cooling tower models would indicate a collapsed condition. Loads were applied to the finite element models in two steps. Dead loads were applied in the first step and wind pressures in the second step.

In the dead load analysis, stresses in the veil were examined to determine the effects of removal of concrete on increased compres-
Cooling Tower Testing Services - when accuracy and efficiency count!

- Thermal Performance
- Heat Rejection Cycle Analysis
- Drift Emissions
- Drift Droplet Size Distribution
- Plume Abatement
- Water Flow Rate
sion in the concrete surrounding the removal areas. Figure 12 and Figure 13 show the distribution of maximum compressive stresses in the veil for the as-designed model and distressed condition model (model with concrete removal), respectively. The maximum compressive stresses were between 9 and 13 times less than the design compressive strength of the veil concrete. Figure 14 and Figure 15 show close-up views of the maximum compressive stresses in models without and with concrete removal, respectively. The maximum increase in compressive stress in the veil concrete surrounding removal areas was about 39%. Though significant, this increase resulted in a maximum stress about 9 times less than the design compressive strength of the surrounding concrete. The wind load analysis was further subdivided into several sub-steps. This was done primarily to facilitate convergence of the path-dependent non-conservative nonlinear analysis conducted and secondly, to provide enough data from which the response of the structure could be monitored. The response of the as-designed model is discussed in the following paragraphs. The behavior of the distressed-condition model is in general similar.

Structural response of the model was linear up to a wind speed of about 52 m/s (117 mph). The linear response corresponded to the relief of pre-compression on the veil structure caused by gravity loads by wind pressure. A slight increase in wind speed (about 1 m/s) led to a sudden loss of stiffness in the veil caused by extensive cracking of concrete in a region bounding the windward meridian and a corresponding sharp increase in steel tensile stress. With further increase in wind speed steel began to yield accompanied by local crushing of concrete and veil crippling (local buckling) below the throat. Between winds speeds of 53 m/s (119 mph) and 63 m/s (140 mph) plastic strains gradually developed in steel. In addition cracks gradually spread circumferentially from the windward meridian accompanied by further crushing of concrete in the vicinity of the windward meridian (Figure 16 and Figure 17). At a speed of about 63 m/s (140 mph) the tower suddenly buckled, leading to very large deformations and a complete loss of stiffness (Figure 17 through Figure 21). The tower model was considered to have collapsed at this wind speed. Wind speeds associated with collapse of the as-designed and the distressed-condition models are presented in Table 2.

Per the Saffir/Simpson scale, collapse loads determined for the as-designed and distressed-condition models correspond to Category 3 and Category 2 hurricanes, respectively. These hurricane categories together with observed behavior of the models were used as bounds within which to provide phasing plans for repairs.

<table>
<thead>
<tr>
<th>Saffir/Simpson Hurricane Category</th>
<th>Gust Wind Speed Over Land* (mph)</th>
<th>Sustained Wind Speed Over Water* (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>82-108</td>
<td>74-95</td>
</tr>
<tr>
<td>2</td>
<td>109-130</td>
<td>96-110</td>
</tr>
<tr>
<td>3</td>
<td>131-156</td>
<td>111-130</td>
</tr>
<tr>
<td>4</td>
<td>157-191</td>
<td>131-155</td>
</tr>
<tr>
<td>5</td>
<td>&gt;191</td>
<td>&gt;155</td>
</tr>
</tbody>
</table>

* 3-second gust wind speed at 33 ft above open ground in Exposure Category C
* 1-minute average wind speed at 33 ft above open water

Table 3. Approximate relationship between wind speeds and Saffir/Simpson hurricane scale (2)

CONCLUSIONS

Results of the analysis showed that the cooling towers have limited reserve wind load capacity in the as-designed condition per ACI 318-08 and ASCE 7-05 requirements. In addition, existing corrosion-induced concrete distress and reduction in the effective area of cross section of reinforcing bars had further diminished structural capacity. It was expected that any future damage resulting from the concrete removal process for surface repairs and cathodic protection installation would further diminish structural capacity. Results from the as-designed condition and distressed-condition analyses were used as upper and lower bounds for formulating phasing plans with the goal of maintaining the towers in a safe and operational condition during repair implementation. Since analyses results showed minimal compromise to structural integrity for non-hurricane wind pressures and a greater impact on the structural integrity for hurricane wind pressures, phasing plans specific to non-hurricane (December 1 – May 31) and hurricane seasons (June 1 – November 30) were prepared. The phasing plans were in the form of constraints which are discussed in detail in the sections below. Because of the limited reserve wind load capacity of the towers in the as-designed condition, hurricane season constraints were more stringent compared with non-hurricane season constraints. Constraints pertaining to each season were based on the structural behavior revealed in the analytical studies, modeling assumptions that were based on original construction drawings, condition surveys, and engineering judgment.

Veil Surface Repair

Constraints were prepared for non-hurricane (December 1 – May 31) and hurricane seasons (June 1 – November 30). It was also recommended that swing-stages or other vertical access systems used for access to the veil surface be positioned in a symmetrical manner for a generally symmetrical execution of the repairs on the veil.

General Constraints

Constraints in this section are applicable to hurricane and non-hurricane seasons:

1. Concrete Removal and Surface Repairs

   i. Lifts 1 through 3 and 65 through 67: Maximum safe depth of concrete removal in the thicker veil sections was determined to be 10 cm (4 in.).

Table 2. Analytically determined collapse wind speeds

<table>
<thead>
<tr>
<th>Wind Speed, m/s (mph)</th>
<th>As-designed Model</th>
<th>Distressed-Condition Model*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-sec gust</td>
<td>1-minute average</td>
<td>3-sec gust</td>
</tr>
<tr>
<td>1</td>
<td>51 (113)</td>
<td>51 (113)</td>
</tr>
<tr>
<td>2</td>
<td>58 (129)</td>
<td>58 (129)</td>
</tr>
<tr>
<td>3</td>
<td>63 (140)</td>
<td>63 (140)</td>
</tr>
<tr>
<td>4</td>
<td>68 (150)</td>
<td>68 (150)</td>
</tr>
<tr>
<td>5</td>
<td>&gt;83</td>
<td>&gt;83</td>
</tr>
</tbody>
</table>

* Distressed condition includes concrete delamination and spalled conditions
ii. Lifts 4 through 64: Maximum safe depth of concrete removal was considered to be 9 cm (3.5 in.).

iii. Where the reinforcement has a loss in cross sectional area, augmentation needs to be done in general conformance to ICRI 03730 guidelines (7).

iv. For compatibility purposes, the compressive strength of repair material at 28 days needs to be consistent with that of the originally specified concrete strength.

**Additional Constraints for Non-Hurricane Season**

1. Bottom Band (Lifts 1 through 39)
   i. It was determined that a maximum of 37 m (120 feet) width can be worked on safely within this band.

2. Top Band (Lifts 40 through 67)
   i. Analysis indicated that a maximum of 24 m (80 feet) of width can be repaired within this band.
   ii. Analysis indicated that for each 24 m (80 feet) of width, concrete removal and surface repairs needed to be completed for either the top or bottom 14 lifts within this band before initiating concrete removal for the remaining 14 lifts.

**Additional Constraints for Hurricane Season**

1. Top Band (Lifts 40 through 67)
   i. It was determined that a maximum width of 12 m (40 feet) could be worked on safely within this band.
   ii. Analysis indicated that for each 12 m (40 feet) of width, concrete removal and surface repairs needed to be completed for either the top or bottom 14 lifts within this band before initiating concrete removal for the remaining 14 lifts.

2. Maximum Time Lapse between Concrete Removal and Repair Material Placement
   i. For the purpose of maintaining continuity between concrete removal and repair it was advised that repair material placement be scheduled no later than 72 hours after removal of concrete from an area. In addition, if an area had been open for more than 72 hours, no additional concrete removal was to be conducted within this band until concrete placement for the open repair cavities was completed.

3. Hurricane Warning
   i. It was advised that in the event of a hurricane warning affecting the region in which the towers are located, all concrete removal operations cease and an attempt be made to complete surface repairs for open repair cavities on a best effort basis.

**General Concluding Comments**

The above constraints are for a specific cooling tower with generally known distress conditions. Cooling towers vary in height and geometry and are subject to different wind load conditions depending on their location. When a repair program is undertaken for any cooling tower, careful analysis needs to be conducted in both the existing and distressed conditions to fully understand their capacities and constraints that need to be imposed in executing the work to maintain structural integrity of the relatively thin shell structure.

**REFERENCES**

1. American Concrete Institute, Building Code Requirements for Structural Concrete and commentary, ACI 318-08.
FULL HOUSE.

POWER-GEN INTERNATIONAL
December 13 - 15, 2011
Las Vegas, Nevada • Las Vegas Convention Center | Central Halls • www.power-gen.com

SAVE THE DATE!

Owned & Produced By: PennWell
Presented By: POWER Engineering
Supported By: PennEnergy
Figure 2. ANSYS finite element model

Figure 3. Finite element model of circumferential columns

Figure 4. Orientation of reinforcement within elements

- Green (horizontal) lines represent circumferential steel
- Red (vertical) lines represent meridional steel

Figure 5. Schematic of distress envelope

Figure 6. As-designed column section

Figure 7. Observed locations of distress to columns
JOIN US NEXT YEAR FOR:

Pump and Turbo

2011

September 12-15, 2011

40th Turbomachinery Symposium
Figure 8. Model of distressed column section

Figure 9. Pressure contours (ksf) for 100mph wind

Figure 10. Pressure contours (ksf) for 100mph wind

Figure 11. Envelope of pressure distribution around tower circumference

Figure 12. Distribution of maximum compressive stresses under dead load (as-designed)

- Wind in negative X direction (from right to left)
- Stress contours in units of kip/ft^2
Figure 13. Distribution of maximum compressive stresses under dead load (distressed-condition)

- Stress contours in units of kip/ft²

Figure 14. Close-up of maximum compressive stresses under dead load (as-designed)

- Stress contours in units of kip/ft²

Figure 15. Close-up of maximum compressive stresses under dead load (distressed-condition)

- Stress contours in units of kip/ft²

Figure 16. Cracks prior to collapse (isometric view)

- Blue outline represents un-cracked elements
- Red, green, and yellow colors represent cracked elements
- Wind in negative X direction (from right to left)

Figure 17. Cracks prior to collapse (plan view)

- Blue outline represents un-cracked elements
- Red, green, and yellow colors represent cracked elements
- Wind in negative X direction (from right to left)
Figure 18. Cracks at collapse (isometric view)
- Blue outline represents un-cracked elements
- Red, green, and yellow colors represent cracked elements
- Wind in negative X direction (from right to left)

Figure 19. Cracks at collapse (plan view)
- Blue outline represents un-cracked elements
- Red, green, and yellow colors represent cracked elements
- Wind in negative X direction (from right to left)

Figure 20. Deformed shape at collapse – circumferential buckling (isometric view)

Figure 21. Deformed shape at collapse (elevation view)
Moore Sets The Standard In Axial Flow Fans.

Since 1940, Moore Fans has provided customers with high-efficiency, high-quality Axial Flow Fans for industrial applications worldwide. Operating in air-cooled heat exchangers, cooling towers, and radiators, Moore fans keep liquids cool in refineries, power plants, process plants, gas compressors and limitless other industrial settings.

Special Design Features Of The Class 10000 Fan

- Resilient Blade Mounting — For more than half a century, all Moore fan blades have been designed with a resilient blade mount, virtually eliminating all moment forces on the hub and shaft, improving durability, ideal under extreme operating conditions.
- Chord Width — Improve performance with fewer number blades for the same performance requirements, resulting in a lower overall cost.
- Blade Angle Adjustment — Blades are factory, preset for specified performance conditions eliminating the need to set during field installation.
- Ring Depth — Designed to operate in a reduced fan ring depth.
- Adjustable Diameter — Designed to permit fan diameter adjustment by as much as +/- 1.5 inches (3.8 cm), greatly easing installation.
- Ideal For Variable Speed — With Moore’s resilient mount system, there are virtually no critical speeds to be avoided.
- Available Blades — Available in both odd and even number of blades, up to 16.
- Low Noise — Where noise levels are critical, combine Vortex tips, wider chord width and increased number of blades for maximum noise reduction.
- Strengthened Design — For engine drive and larger fan diameter applications from four to 24 feet.

Today, Moore Fans has some 175,000 fans in operation around the world. And with sales offices in North America and in Europe, Moore factory engineers and customer service representatives stand ready to help you analyze your air moving requirements, choose the right product, and provide reliable service and support, before and after the sale.

For more information on the Class 10000 Fans or any of the family of quality products from Moore Fans call 660-376-3575 or visit us online at moorefans.com.
Copper Corrosion Control And Minimized Copper Discharge From Cooling Tower

Jasbir S. Gill, Ph.D.
Ed Grodecki
Nalco Company, Naperville, IL

Abstract

Waterside corrosion of copper alloy surface condensers and heat exchangers not only compromises the asset integrity but also results in the release of toxic copper corrosion products to the environment. Faced with new NPDES discharge limits for copper, many industrial systems have a strong desire to control corrosion and minimize copper discharge. This paper discusses the development of a comprehensive cooling water treatment program at a power plant to reduce corrosion of the main surface condenser and minimize copper discharge at the final outfall. Different aspects of the copper discharge reduction program, including, management of cooling system operations, optimization of cooling water pH, improvements to the microbiological control program and the application of a newly-developed halogen stable azole corrosion inhibitor are discussed.

Introduction – Regulatory Challenges

In February 2005, the Ohio EPA imposed a new limit on the amount of total copper being discharged directly to the river from the combined circulating water system and service water system outfall at the Power Plant on the Ohio River. The current NPDES permit is in effect from February 1, 2005 to January 31, 2010 and requires compliance with the new copper discharge limit by the last year of the permit, starting in February 2009. Initially, the total copper discharge limit was 54 ppb, with a maximum loading of 3.7 kg/day. Both criteria were to be met. Because there is no sample point available at the actual outfall, a flow-weighted average (FWA) calculation is used to determine discharge compliance. The FWA calculation takes into account flows and concentrations of copper from both cooling tower blowdown and service water streams. Historically, copper levels in the circ water and service water were not routinely tested. Starting in March 2005, copper concentrations were analyzed (using atomic absorption) 3 times per week on both the main condenser cooling and service water systems. Prior to March 2005, the total copper concentration of the circulating water system had been measured only twice, with results of 850 ppb (1997) and 480 ppb (2003).

Well in advance of the compliance date, the Power Plant personnel requested that the Ohio EPA consider alternative discharge limits and/or methodologies to calculate and report discharge concentrations of copper. The Ohio EPA agreed to consider two options. The first option was the use of a dissolved metals translator (DMT) approach. DMT is the ratio of a total metal present to the dissolved fraction of that total. The dissolved quantity is most important to regulate because it is the toxic form of copper.

The second option of reporting copper was to consider a mixing zone allowance. The station decided to pursue the DMT option and began a clean sampling program late 2005 to develop the data needed to support this DMT option. The samples were collected using plastic gloves and bags, a plastic tented box and syringes with filters and dissolved copper was measured from the filtered samples. The Ohio EPA approved this methodology and raised the (total) copper discharge limit at Power plant Station to 92 ppb, with a maximum loading to the Ohio River of 11.1 kg/day, effective March 1, 2009.

Cooling Water System Design and Operation

The Power Plant operates a single, 1400 MW, B&W supercritical steam generator that began operation in 1991. Unit 1 produces approximately 10-million lbs/hr steam, part of which is utilized for the steam-driven boiler feed pump. The main condenser contains 28,602 tubes of 90-10 Cu-Ni and 1,500 tubes of 70-30 Cu-Ni in the air removal section. The condenser tubes are 18 gauge, 1 inch OD, and 70 ft long. The boiler feed pump auxiliary condenser contains 16,826 tubes of 90-10 Cu-Ni and these are also 18 gauge, 1 inch OD, and 70 feet long. Table 1 shows several design and operating parameters for the Power Station’s main condenser cooling water system.

Well in advance of the compliance date, the Power Plant personnel requested that the Ohio EPA consider alternative discharge limits and/or methodologies to calculate and report discharge concentrations of copper. The Ohio EPA agreed to consider two options. The first option was the use of a dissolved metals translator (DMT) approach. DMT is the ratio of a total metal present to the dissolved fraction of that total. The dissolved quantity is most important to regulate because it is the toxic form of copper.

The second option of reporting copper was to consider a mixing zone allowance. The station decided to pursue the DMT option and began a clean sampling program late 2005 to develop the data needed to support this DMT option. The samples were collected using plastic gloves and bags, a plastic tented box and syringes with filters and dissolved copper was measured from the filtered samples. The Ohio EPA approved this methodology and raised the (total) copper discharge limit at Power plant Station to 92 ppb, with a maximum loading to the Ohio River of 11.1 kg/day, effective March 1, 2009.

Cooling Water System Design and Operation

The Power Plant operates a single, 1400 MW, B&W supercritical steam generator that began operation in 1991. Unit 1 produces approximately 10-million lbs/hr steam, part of which is utilized for the steam-driven boiler feed pump. The main condenser contains 28,602 tubes of 90-10 Cu-Ni and 1,500 tubes of 70-30 Cu-Ni in the air removal section. The condenser tubes are 18 gauge, 1 inch OD, and 70 ft long. The boiler feed pump auxiliary condenser contains 16,826 tubes of 90-10 Cu-Ni and these are also 18 gauge, 1 inch OD, and 70 feet long. Table 1 shows several design and operating parameters for the Power Station’s main condenser cooling water system.

Table 1

<table>
<thead>
<tr>
<th>Power Plant Circulating System Parameters</th>
<th>Hyperbolic, natural draft</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling tower type</td>
<td>Plastic, splash bar</td>
</tr>
<tr>
<td>Cooling tower fill material</td>
<td>Plastic, splash bar</td>
</tr>
<tr>
<td>Cooling system volume, gallons</td>
<td>6,000,000</td>
</tr>
<tr>
<td>Recirculation rate, gallons/minute</td>
<td>465,000</td>
</tr>
<tr>
<td>Surface condenser tube metallurgy</td>
<td>90-10 Cu-Ni (majority)</td>
</tr>
<tr>
<td>Cooling water temperature, deg. F, condenser in/out</td>
<td>96/121 (summer)</td>
</tr>
<tr>
<td>Cycles of concentration</td>
<td>2-5</td>
</tr>
<tr>
<td>Cooling tower makeup, gallons per minute</td>
<td>12,000-15,000</td>
</tr>
<tr>
<td>Cooling tower blowdown, gallons per minute</td>
<td>3,000-5,000</td>
</tr>
</tbody>
</table>

Figure 1 shows the cooling water system configuration, including the (recirculating) main condenser cooling system and the (once-through) service water-cooling system. As shown, the discharge flow from the service water system combines with the cooling tower blowdown from the circulating system to form the total plant discharge flow. Flow through the service water system varies seasonally. During the colder months, with a single service water pump in operation, service water flow is ~ 5,500 gpm. Flow increases to ~15,000 gpm during the warmer months when additional service water pumps are in operation. Total service water flow dilutes the
COOLING TOWER INSPECTION & REPAIR

Bleed-through, spalls and cracks are the beginning signs of deterioration. Our inspectors and engineers can provide detailed inspections, including shape surveys and strength calculations, leading to any necessary shell repairs.

With our sister company Bierum, who specializes in the design and construction of hyperbolic cooling towers around the world, we have access to proprietary rigging and engineering services for hyperbolic cooling towers.

We have completed repairs to cooling towers shells, lintel beams and columns. Replacing ladders, platforms, and lightning protection is routine; and now inspections with an engineering review are all within our scope.

INTERNATIONAL CHIMNEY CORPORATION

55 South Long Street, Williamsville, NY 14221

800-828-1446 Phone: 716-634-3967
www.internationalchimney.com Fax: 716-634-3983

Email: gms@internationalchimney.com
cooling tower blowdown and thereby has a direct impact on copper concentration at the regulated outfall.

Figure 1: Simplified Flow Diagram, Circulating and Service Water Systems

Makeup for the Power plant’s cooling water system is raw, un-clarified Ohio River water (service water). Table 2 shows typical values for several water quality parameters for the Ohio River. There is significant seasonal variability in total suspended solids (TSS) in the Ohio River, as shown in Figure 2. The highest levels of TSS occur in the winter and spring and are associated with periods of runoff from snowmelt and rainfall.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.6-7.8</td>
</tr>
<tr>
<td>Total alkalinity, ppm</td>
<td>50-80</td>
</tr>
<tr>
<td>Ca, ppm as Ca</td>
<td>70-110</td>
</tr>
<tr>
<td>Mg, ppm</td>
<td>40-60</td>
</tr>
<tr>
<td>Chloride, ppm</td>
<td>35-60</td>
</tr>
<tr>
<td>Sulfate, ppm</td>
<td>60-80</td>
</tr>
<tr>
<td>Manganese, ppm</td>
<td>0.1-0.2</td>
</tr>
<tr>
<td>Conductivity, uS/cm</td>
<td>300-500</td>
</tr>
</tbody>
</table>

Table 2
Ohio River Water Quality

Figure 2
Ohio River TSS and Temperature (2008)

Cycles of concentration are controlled at 4-5 during the warmer months to minimize water treatment chemical costs and conserve water. During the cooler months when TSS are highest, cycles of concentration are reduced primarily to keep TSS below ~250 ppm in the circulating water system. TSS levels can significantly impact the concentration of copper in the discharge by scouring the tube surface and also placing a demand on azole copper corrosion inhibitor.

To control calcium carbonate scale deposition within the condenser, pH is controlled with sulfuric acid, the Langelier Saturation Index (LSI) is maintained at ~1.0. Also, a residual of 1.0 to 1.5 ppm of phosphonate (HEDP) is maintained in the circ water. The Power plant cooling water treatment program does not include use of a silt dispersant.

Factors That Impact Copper Discharge

Several key factors impact the concentration of copper (Cu ppb) in the discharge stream at Power plant Station. First, as shown in Figure 3, the Ohio River makeup water contributes an average background total copper level of ~5 ppb, with an annual high value of ~25 ppb as measured during 2008. With cycling due to evaporation within the cooling tower, makeup water copper values are concentrated 2 to 5 times and therefore can contribute significantly toward the total discharge concentration.

Figure 3
Ohio River (Makeup) Water Total Copper (2008)

At Power plant Station, corrosion of copper alloys and release of copper corrosion products (copper throw) from the main condenser and service water heat exchangers contributes the highest percentage of the total copper in the discharge. Corrosion of copper alloys in cooling water systems can be driven by many factors, including water temperature, cooling water pH, total dissolved solids (TDS), ammonia, velocity, biofouling deposits, MIC-related organisms, inorganic deposits such as mud and silt, etc. Aggressive anions, particularly chlorides, degrade the protective cuprous oxide (Cu2O) film and induce localized pitting attack.

The concentration and frequency of application of commonly used water treatment chemicals such as acid and bleach contributes significantly to copper corrosion rates and total copper discharge concentration. The relative copper corrosion rate in a cooling water system is largely affected by pH. Copper corrosion in both cooling and boiler water systems is minimized at ~8.9. Any pH depression due to intentional or unintentional overfeed of sulfuric acid can significantly impact the level of the total copper that is measured in the bulk water.

Copper corrosion is accelerated in the presence of oxidizing biocides that are added to the cooling system to control microbiological growth. However if too little oxidizing biocide is used, biological growth can lead to flow restrictions, poor heat transfer and corrosion caused by deposits. Just as with overfeed of acid, excessive use of oxidizing biocides such as chlorine and bromine can accelerate copper corrosion, shorten asset life, and produce corrosion products that contribute to the concentration of copper in the discharge.
Rev Up for Indy in 2011

27th ANNUAL INTERNATIONAL FEW
FUEL ETHANOL WORKSHOP & EXPO
an Ethanol Producer Magazine event

June 27 - 30, 2011
Indianapolis, Indiana USA

www.fuelethanolworkshop.com
Understanding the overall cooling system water balance, and contribution of copper from various sources, is key to managing and minimizing copper in the discharge. At Power plant Station, cooling system discharge is a combination of flows (and contribution of copper concentrations) from cooling tower blowdown and once-through service water flow. Unfortunately there is no single sample point at the outfall for these combined cooling water flows and therefore no direct measurement of the outfall copper concentration is available. The level of total copper in the final outfall (reported in ppb and kg/day) is determined using a set of flow weighted average (FWA) calculations; these take into account the flow of blowdown and service water, plus the concentration of copper as routinely tested in these flow streams.

\[ \text{FWA}\text{ppb} = \frac{\left[ (\text{CuBD} \times \text{FlowBD} + \text{CuSW} \times \text{FlowSW}) \right]}{\left[ \text{FlowBD} + \text{FlowSW} \right]} \text{ ppb} \]

\[ \text{FWA}\text{loading} = \frac{\left[ (\text{CuBD} \times \text{FlowBD} + \text{CuSW} \times \text{FlowSW}) \times 8.34 \right]}{1,000 \text{ lbs/day} \times 0.454 \text{ kg/day}} \]

Note: Cu values are in ppb and Flow values are in million gallons per day.

**Copper Discharge Reduction Program**

Several key actions were taken to minimize the impact of the various factors that contribute to the concentration of copper in the discharge. Together, these actions provide a comprehensive program for achieving and maintaining copper discharge compliance at Power plant Station.

- **Optimization of cooling water pH, improved pH control**

To promote the formation of a protective cuprous oxide film and reduce the generation of corrosion products, the pH target set point was increased from 8.0 year round to 8.2 - 8.6. The pH is adjusted within the 8.2-8.6 range based on seasonal factors that contribute to the calculated LSI value. Additionally, steps are being taken to improve the reliability and consistency of pH control. In the past there were failures of the pH control system (due to pH probe failure or loss of water flow to the probe) and these events resulted in severe pH depression, severe corrosion and consequently the release of copper to the discharge. In order to maintain the new copper discharge restrictions, greater emphasis is being placed on maintenance of the pH control system and there are plans to upgrade the existing pH control with a redundant system. Progress is being made in this area as shown in Figure 4.

![Figure 4. Cooling water pH over time](image)

Prior to increasing the cooling water pH set point, we evaluated the potential impact on calcium carbonate scaling tendencies using the modeling tool. Power plant personnel routinely monitor condenser performance. Condenser cleanliness factor has been maintained above the target 85% while operating at the higher pH set point, thus indicating that the higher potential for calcium carbonate scale is being controlled.

- **Improved microbiological control treatment**

Previously the microbiological control regime was to shock dose the cooling tower system with high doses of bleach on a weekly basis during the summer months and biweekly basis during the winter months. At Power plant Station baseline (traditional azole only) conditions, condenser copper throw values increased from an average of 8.1 lb/day to 11.3 lb/day (~ 25%) on those days that bleach was slug fed to the cooling tower basin.

To reduce the overall halogen residual, reduce copper corrosion and improve microbiological control, a new stabilized bromine chemistry was evaluated. A stabilized bromine product that reduces the volatilization of chlorine over the cooling tower. Studies have shown that as much as 20% of the chlorine residual in the cooling water is stripped with each pass over the cooling tower. The addition of stabilized bromine product provides stabilized forms of bromine and chlorine that have been shown to penetrate and remove biofilm better than chlorine alone. The stabilized bromine program is providing improved microbiological/biofilm control with lower halogen residuals, thus reducing the negative impact to copper corrosion and discharge. The longer halogen residence time with stabilized bromine as measured in the recirculating cooling water system is shown in Figure 5. Evaluation of the stabilized bromine treatment has demonstrated improved microbiological control with a 50% reduction in bleach addition at Power plant Station.

![Figure 5. Halogen Profile: Bleach Only vs. Bleach Plus Stabilized bromine](image)

- **Advanced halogen stable azole copper corrosion inhibitor**

Azoles function by ligand bonding of the nitrogen atoms to the copper surface, where the plate-like organic rings overlay the surface with a protective barrier film. A difficulty with these compounds is that they are subject to degradation by oxidizing biocides. Azole films are also susceptible to mechanical scouring.

A key element of the copper reduction program at Power plant Station is the use of a newly developed halogen stable azole chemistry. The chemical structure of this new treatment contains an organic component, which greatly increases stability towards oxidizing biocides, and improves the nitrogen-copper bond strength, which helps to reduce the effect of scouring. Scouring occurs when the abrasive action of TSS on condenser tube surfaces removes copper corrosion products that in turn contribute to the concentration of total copper in the bulk water. The benefit of the halogen stable azole (a proprietary composition) product is shown in Figure 7. The average rate of copper throw from the Power plant condenser was reduced from 6.9 to 5.5 lb/day (20%) with the HSC treatment.
SB is stabilize bromine, and HSC is high stress proprietary corrosion Inhibitor

- Management of the copper reduction program to deal with various conditions

The treatment program has been modified over the past 18 months to account for seasonal conditions and abnormal operations that can contribute to higher levels of copper in the discharge. For example, during the months when TSS are highest in the river water makeup, typically December through May, the tower cycles are reduced to ~3 to maintain <250 TSS in the recirculating water. It has been observed at Power plant that high TSS places a demand on the azole copper corrosion inhibitors. Azoles are readily adsorbed onto suspended solids and thereby become unavailable to form a barrier film on condenser tubes to inhibit corrosion. Fortunately the river water makeup contains lower calcium and alkalinity during the seasonal periods when TSS levels are highest. Consequently the recirculating cooling water system can be operated with a higher pH set point while maintaining an acceptable LSI. This provides the added benefit of reducing overall sulfuric acid usage, which resulted in a significant cost savings to the plant. Table 3 summarizes the operational changes that are made to the cooling water program to deal with the seasonal variability in water quality (particularly TSS), outage conditions and times when condenser leaks occur. In addition to improving performance (reduction in copper discharge) several of these actions are taken to minimize overall chemical treatment usage and cost.

Table 3
Cooling System Operating Conditions

---

The best sheaves for the worst environments!

Ideally suited for the most aggressive atmospheres, unusual conditions, such as weight requirements and installation problems, Bailsco lightweight all-aluminum cast V-belt sheaves have been in the field for over 15 years.

Full range of sizes available up to 38” diameter, larger sizes available upon request.
Special designs to meet OEM requirements.
Design, molding, casting, machining, heat treating and balancing are all done “in-house”.

BAILSCO POWER TRANSMISSION PRODUCTS

BAILSCO BLADES AND CASTINGS, INC.
Box 6093, Shreveport, LA 71136-6093 U.S.A.
Phone 318.861.2137 FAX 318.861.2953
www.bailsco.com
e-mail: bailsco@bailsco.com
Conclusions

The total water management approach to controlling copper levels in the Power plant outfall has proven to be successful; Power plant Station is achieved compliance with the new copper discharge regulation of 54 ppb and 3.7 kg/day that went into effect on February 1, 2009, and has maintained compliance with the new DMT based limit of 92 ppb and 11.1 kg/day that went into effect on March 1, 2009.

The use of a traditional azole treatment alone, with no further changes to the water treatment program or plant operations would not be sufficient to achieve compliance with these new copper discharge limits. Primarily this is because the traditional azole program could not mitigate the negative effects of high TSS and the impact of high levels of halogenation. Despite achieving a 60% reduction in the copper corrosion rate from untreated conditions with traditional azole alone, the average copper throw from the condenser was 8.1 pounds per day. In order to maintain compliance with both the concentration limit and the loading limit, the plant had to lower the copper throw from the condenser to less than 6 pounds per day.

Improvements to the microbial control and pH control programs showed a 15% decrease in copper throw, from 8.1 lbs/day to 6.9 lbs/day. These program changes also resulted in significant reductions in usage and cost for bleach and acid. Even with these changes, however, the level of copper throw from the condenser was still not below the value needed for discharge compliance, i.e., 6 pounds per day.

The proprietary copper corrosion treatment program was started during May 2008 and an additional 20% decrease in copper throw (down to 5.5 lbs/day from 6.9) was observed. Additionally, the improvement in the nitrogen-copper bond strength of the proprietary copper corrosion treatment program was immediately apparent during a June 5th high TSS event. During that event copper throw from the condenser increased only slightly to 5.56 pounds/day, i.e., considerably lower than the two previous high TSS events when copper throw reached 15.3 and 10.8 pounds/day.

Further improvements to the Power plant copper reduction program are being implemented. To better understand the operational and water quality dynamics that drive copper corrosion and discharge, a unique proprietary monitoring and control unit is being installed. The unique proprietary monitoring and control unit will significantly improve the monitoring capabilities and allow chemical addition based on real-time demand.
For nearly thirty years, the Cooling Technology Institute has provided a truly independent, third party, thermal performance testing service to the cooling tower industry. In 1995, the CTI also began providing an independent, third party, drift performance testing service as well. Both these services are administered through the CTI Multi-Agency Tower Performance Test Program and provide comparisons of the actual operating performance of a specific tower installation to the design performance. By providing such information on a specific tower installation, the CTI Multi-Agency Testing Program stands in contrast to the CTI Cooling Tower Certification Program which certifies all models of a specific manufacturer's line of cooling towers perform in accordance with their published thermal ratings.

To be licensed as a CTI Cooling Tower Performance Test Agency, the agency must pass a rigorous screening process and demonstrate a high level of technical expertise. Additionally, it must have a sufficient number of test instruments, all meeting rigid requirements for accuracy and calibration.

Once licensed, the Test Agencies for both thermal and drift testing must operate in full compliance with the provisions of the CTI License Agreements and Testing Manuals which were developed by a panel of testing experts specifically for this program. Included in these requirements are strict guidelines regarding conflict of interest to insure CTI Tests are conducted in a fair, unbiased manner.

Cooling tower owners and manufacturers are strongly encouraged to utilize the services of the licensed CTI Cooling Tower Performance Test Agencies. The currently licensed agencies are listed below.

### Licensed CTI Thermal Testing Agencies

<table>
<thead>
<tr>
<th>License Type*</th>
<th>Agency Name</th>
<th>Contact Person</th>
<th>Telephone</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>A,B</td>
<td>Clean Air Engineering</td>
<td>Kenneth Hennon</td>
<td>800.208.6162</td>
<td>865.938.7569</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.cleanair.com">www.cleanair.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:khennon@cleanair.com">khennon@cleanair.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A, B</td>
<td>Cooling Tower Technologies Pty Ltd</td>
<td>Ronald Rayner</td>
<td>61 2 9789 5900</td>
<td>61 2 9789 5922</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:coolingtwrtech@bigpond.com">coolingtwrtech@bigpond.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A, B</td>
<td>Cooling Tower Test Associates, Inc.</td>
<td>Thomas E. Weast</td>
<td>913.681.0027</td>
<td>913.681.0039</td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.cttai.com">www.cttai.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:cttake@aol.com">cttake@aol.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="http://www.mchale.org">www.mchale.org</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><a href="mailto:tom.wheelock@mchale.org">tom.wheelock@mchale.org</a></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Type A license is for the use of mercury in glass thermometers typically used for smaller towers.
* Type B license is for the use of remote data acquisition devices which can accommodate multiple measurement locations required by larger towers.

### Licensed CTI Drift Testing Agencies

<table>
<thead>
<tr>
<th>Agency Name</th>
<th>Contact Person</th>
<th>Telephone</th>
<th>Fax</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean Air Engineering</td>
<td>Kenneth Hennon</td>
<td>800.208.6162</td>
<td>865.938.7569</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.cleanair.com">www.cleanair.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><a href="mailto:khennon@cleanair.com">khennon@cleanair.com</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td>McHale &amp; Associates, Inc</td>
<td>Thomas Wheelock</td>
<td>865.588.2654</td>
<td>425.557.8377</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.mchale.org">www.mchale.org</a></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><a href="mailto:tom.wheelock@mchale.org">tom.wheelock@mchale.org</a></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As stated in its opening paragraph, CTI Standard 201... "sets forth a program whereby the Cooling Technology Institute will certify that all models of a line of water cooling towers offered for sale by a specific Manufacturer will perform thermally in accordance with the Manufacturer's published ratings..." By the purchase of a "certified" model, the Owner/Operator has assurance that the tower will perform as specified, provided that its circulating water is within acceptable limits and that its air supply is ample and unobstructed. Either that model, or one of its close design family members, will have been thoroughly tested by the single CTI-licensed testing agency for Certification and found to perform as claimed by the Manufacturer.

CTI Certification under STD-201 is limited to thermal operating conditions with entering wet bulb temperatures between 12.8°C and 32.2°C (55°F to 90°F), a maximum process fluid temperature of 51.7°C (125°F), a cooling range of 2.2°C (4°F) or greater, and a cooling approach of 2.8°C (5°F) or greater. The manufacturer may set more restrictive limits if desired or publish less restrictive limits if the CTI limits are clearly defined and noted in the publication.

In addition, 6 of the manufacturers also market products as private brands through other companies. While in competition with each other, these manufacturers benefit from knowing that they each achieve their published performance capability and distinguish themselves by providing the Owner/Operator’s required thermal performance. The participating manufacturers currently have 58 product lines plus 8 product lines marketed as private brands which result in more than 8,500 cooling tower models with CTI STD-201 Thermal Performance Certification for cooling tower Owner/Operator’s to select from. The following table lists the currently active cooling tower manufacturers, their products with CTI STD-201 Thermal Performance Certification, and a brief description of the product lines.

Those Manufacturers who have not yet chosen to certify their product lines are invited to do so at the earliest opportunity. You can contact Virginia A. Manser, Cooling Technology Institute, PO Box 73383, Houston, TX 77273 for further information.
<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product Line</th>
<th>C.T.I. Certification Validation Number</th>
<th>Revision Number</th>
<th>Date</th>
<th>Tower Type</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance QRF (Advance) Cooling Towers, Pvt., Ltd.</td>
<td>Advance 2620</td>
<td>07-31-01</td>
<td>1</td>
<td>July 19, 2009</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td>Aggreko Cooling Tower Services</td>
<td>AG</td>
<td>06-34-01</td>
<td>1</td>
<td>July 24, 2010</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td>Amcot Cooling Tower Corporation</td>
<td>LC</td>
<td>96-20-01</td>
<td>2</td>
<td>September 8, 2007</td>
<td>Open Circuit</td>
<td>Cross-flow</td>
</tr>
<tr>
<td>American Cooling Tower, Inc.</td>
<td>ACF</td>
<td>10-38-01</td>
<td>0</td>
<td>June 1, 2010</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td>AONE E&amp;C Corporation, Ltd.</td>
<td>ACT-R</td>
<td>05-28-01</td>
<td>2</td>
<td>January 29, 2010</td>
<td>Open Circuit</td>
<td>Cross-flow</td>
</tr>
<tr>
<td></td>
<td>ACT</td>
<td>06-11-12</td>
<td>1</td>
<td>February 6, 2009</td>
<td>Open Circuit</td>
<td>Cross-flow</td>
</tr>
<tr>
<td></td>
<td>FXT</td>
<td>92-11-01</td>
<td>2</td>
<td>September 22, 2006</td>
<td>Open Circuit</td>
<td>Cross-flow</td>
</tr>
<tr>
<td></td>
<td>FXV</td>
<td>98-11-09</td>
<td>7</td>
<td>March 3, 2006</td>
<td>Closed Circuit</td>
<td>Combined</td>
</tr>
<tr>
<td></td>
<td>PCT</td>
<td>10-11-13</td>
<td>0</td>
<td>April 10, 2010</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>PT2</td>
<td>07-11-11</td>
<td>0</td>
<td>May 5, 2007</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>Series V Closed</td>
<td>00-11-10</td>
<td>1</td>
<td>March 3, 2009</td>
<td>Closed Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>Series V Open</td>
<td>92-11-02</td>
<td>4</td>
<td>January 1, 2004</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>Series 1500</td>
<td>94-11-08</td>
<td>7</td>
<td>September 27, 2010</td>
<td>Open Circuit</td>
<td>Cross-flow</td>
</tr>
<tr>
<td></td>
<td>Series 3000 A, C, &amp; D</td>
<td>92-11-06</td>
<td>10</td>
<td>September 27, 2010</td>
<td>Open Circuit</td>
<td>Cross-flow</td>
</tr>
<tr>
<td></td>
<td>Delta Cooling Tower, Inc.</td>
<td>TM Series</td>
<td>02-24-01</td>
<td>1</td>
<td>January 1, 2010</td>
<td>Open Circuit</td>
</tr>
<tr>
<td></td>
<td>AT Series</td>
<td>98-13-01</td>
<td>10</td>
<td>September 17, 2010</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>ATW</td>
<td>05-13-06</td>
<td>2</td>
<td>September 17, 2010</td>
<td>Closed Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>ESWA</td>
<td>05-13-05</td>
<td>5</td>
<td>January 1, 2010</td>
<td>Closed Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>L Series Closed</td>
<td>05-13-07</td>
<td>1</td>
<td>September 17, 2010</td>
<td>Closed Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>L Series Open</td>
<td>05-13-03</td>
<td>2</td>
<td>September 17, 2010</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>PMWQ</td>
<td>10-13-08</td>
<td>0</td>
<td>April 18, 2010</td>
<td>Closed Circuit</td>
<td>Counter-flow</td>
</tr>
<tr>
<td></td>
<td>PMTQ</td>
<td>10-13-09</td>
<td>0</td>
<td>September 17, 2010</td>
<td>Open Circuit</td>
<td>Counter-flow</td>
</tr>
</tbody>
</table>
## Cooling Towers Certified by the CTI under STD-201

Internet links for the manufacturers, their specific product lines, and the selection information for each product line can be found at:

http://www.cti.org/certification.shtml

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product Line</th>
<th>CTI Certification Validation Number</th>
<th>Revision Number</th>
<th>Date</th>
<th>Tower Type</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HR</td>
<td>04-22-03</td>
<td>1</td>
<td>July 14, 2008</td>
<td>Open Circuit Counter-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>HFC</td>
<td>10-22-06</td>
<td>0</td>
<td>January 31, 2010</td>
<td>Closed Circuit Counter-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>LSFG</td>
<td>05-22-04</td>
<td>0</td>
<td>January 2, 2009</td>
<td>Open Circuit Counter-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>SLSFG</td>
<td>05-22-05</td>
<td>0</td>
<td>January 2, 2009</td>
<td>Open Circuit Counter-flow</td>
<td>Axial</td>
</tr>
<tr>
<td>HVAC/R International, Inc.</td>
<td>Therflow Series TFC</td>
<td>02-06-02</td>
<td>0</td>
<td>January 4, 2010</td>
<td>Closed Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>Therflow Series TFW</td>
<td>02-06-01</td>
<td>2</td>
<td>January 29, 2010</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td>King Sun Industry Company, Ltd.</td>
<td>HKB</td>
<td>05-35-01</td>
<td>0</td>
<td>February 11, 2009</td>
<td>Open Circuit Counter-flow</td>
<td>Centrifugal</td>
</tr>
<tr>
<td></td>
<td>HKD</td>
<td>05-35-02</td>
<td>0</td>
<td>February 14, 2009</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td>KINCO (Kyoung In Machinery Company, Ltd.)</td>
<td>CLK</td>
<td>05-18-02</td>
<td>2</td>
<td>June 15, 2009</td>
<td>Closed Circuit Combined</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>Eco-Dynas Cool</td>
<td>09-06-03</td>
<td>0</td>
<td>September 14, 2009</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>Endura Cool</td>
<td>93-18-01</td>
<td>6</td>
<td>May 17, 2007</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td>Liang Chi Industry Company, Ltd.</td>
<td>C-LC</td>
<td>05-20-02</td>
<td>0</td>
<td>September 4, 2009</td>
<td>Closed Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>L0</td>
<td>96-20-01</td>
<td>2</td>
<td>September 8, 2007</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>U-LC</td>
<td>10-20-04</td>
<td>0</td>
<td>July 4, 2010</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>V-LC</td>
<td>10-20-03</td>
<td>0</td>
<td>July 4, 2010</td>
<td>Open Circuit Counter-flow</td>
<td>Centrifugal</td>
</tr>
<tr>
<td>Metley (SPX Cooling Technologies)</td>
<td>Aquatower Series</td>
<td>01-14-06</td>
<td>2</td>
<td>July 18, 2009</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>AV Series</td>
<td>96-14-04</td>
<td>1</td>
<td>April 11, 2000</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>MCW Series</td>
<td>06-14-08</td>
<td>2</td>
<td>May 1, 2007</td>
<td>Open Circuit Counter-flow</td>
<td>Centrifugal</td>
</tr>
<tr>
<td></td>
<td>MD Series</td>
<td>08-14-11</td>
<td>0</td>
<td>April 2, 2008</td>
<td>Open Circuit Counter-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>MIF Series</td>
<td>04-14-07</td>
<td>1</td>
<td>October 24, 2005</td>
<td>Closed Circuit Combined</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>NG Series</td>
<td>92-14-01</td>
<td>16</td>
<td>January 23, 2009</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
<tr>
<td></td>
<td>Quadraflow</td>
<td>92-14-02</td>
<td>2</td>
<td>April 11, 2000</td>
<td>Open Circuit Cross-flow</td>
<td>Axial</td>
</tr>
</tbody>
</table>
## Cooling Towers Certified by the CTI under STD-201

Internet links for the Manufacturers, their specific product lines, and the selection information for each product line can be found at: [http://www.cti.org/certification.shtml](http://www.cti.org/certification.shtml)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Product Line</th>
<th>CTI Certification Validation Number</th>
<th>Revision Number</th>
<th>Date</th>
<th>Tower Type</th>
<th>Models</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masan Cooling Tower, Ltd.</td>
<td>MCR Series</td>
<td>05-26-02</td>
<td>2</td>
<td>October 10, 2010</td>
<td>Open Circuit</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>MCR-KM Series</td>
<td>08-26-04</td>
<td>1</td>
<td>October 10, 2010</td>
<td>Counter-flow</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>MX Series</td>
<td>10-26-05</td>
<td>0</td>
<td>January 4, 2010</td>
<td>Closed Circuit</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>MXX-KM Series</td>
<td>08-24-03</td>
<td>2</td>
<td>December 7, 2010</td>
<td>Open Circuit</td>
<td>220</td>
</tr>
<tr>
<td>Nilson Spindle Manufacturing Company, Ltd.</td>
<td>CTA-KX Series</td>
<td>08-33-01</td>
<td>0</td>
<td>May 26, 2008</td>
<td>Cross-flow</td>
<td>34</td>
</tr>
<tr>
<td>Pelcol, b. v.</td>
<td>CR Series</td>
<td>04-25-01</td>
<td>0</td>
<td>July 16, 2004</td>
<td>Open Circuit</td>
<td>78 CMC 180 CMDR</td>
</tr>
<tr>
<td></td>
<td>XR Series</td>
<td>04-25-02</td>
<td>0</td>
<td>July 16, 2004</td>
<td>Cross-flow</td>
<td>4 XE 16 XL 27 XT</td>
</tr>
<tr>
<td>Protec Cooling Towers, Inc.</td>
<td>FRS Series</td>
<td>05-27-03</td>
<td>1</td>
<td>January 2, 2009</td>
<td>Open Circuit</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>FWS Series</td>
<td>04-27-01</td>
<td>3</td>
<td>September 29, 2009</td>
<td>Cross-flow</td>
<td>93</td>
</tr>
<tr>
<td>RSD Cooling Towers</td>
<td>RSS Series</td>
<td>08-32-01</td>
<td>0</td>
<td>April 28, 2008</td>
<td>Open Circuit</td>
<td>6</td>
</tr>
<tr>
<td>Ryowo (Holding) Company, Ltd.</td>
<td>FCS</td>
<td>10-27-04</td>
<td>0</td>
<td>February 22, 2010</td>
<td>Cross-flow</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>FRS Series</td>
<td>05-27-03</td>
<td>1</td>
<td>June 18, 2007</td>
<td>Open Circuit</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>FWS Series</td>
<td>04-27-01</td>
<td>3</td>
<td>September 29, 2009</td>
<td>Cross-flow</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>FXS Series</td>
<td>05-27-02</td>
<td>2</td>
<td>September 28, 2010</td>
<td>Open Circuit</td>
<td>30</td>
</tr>
<tr>
<td>Sino Air-Conditioning (Fogang) Co., Ltd.</td>
<td>SC-H Series</td>
<td>10-37-01</td>
<td>0</td>
<td>January 1, 2010</td>
<td>Cross-flow</td>
<td>15</td>
</tr>
<tr>
<td>Ta Shin F. R. P. Company, Ltd.</td>
<td>TSS Series</td>
<td>08-32-01</td>
<td>0</td>
<td>April 28, 2008</td>
<td>Cross-flow</td>
<td>6</td>
</tr>
<tr>
<td>The Cooling Tower Company, L. C.</td>
<td>Series TCI</td>
<td>06-29-01</td>
<td>0</td>
<td>April 7, 2006</td>
<td>Open Circuit</td>
<td>112</td>
</tr>
<tr>
<td>The Trane Company</td>
<td>Series Quiet (TQ)</td>
<td>02-14-01</td>
<td>15</td>
<td>January 23, 2009</td>
<td>Open Circuit</td>
<td>262</td>
</tr>
<tr>
<td>Tower Tech, Inc</td>
<td>TTXL</td>
<td>08-17-06</td>
<td>1</td>
<td>November 29, 2010</td>
<td>Counter-flow</td>
<td>34</td>
</tr>
<tr>
<td>Walco Systems</td>
<td>WGI</td>
<td>09-36-01</td>
<td>0</td>
<td>August 31, 2009</td>
<td>Open Circuit</td>
<td>236</td>
</tr>
<tr>
<td>Zhejiang Jinling Refrigeration Engineering Co., Ltd.</td>
<td>JNC Series</td>
<td>09-28-02</td>
<td>0</td>
<td>January 5, 2009</td>
<td>Closed Circuit</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>JNT Series</td>
<td>05-28-01</td>
<td>2</td>
<td>January 19, 2010</td>
<td>Open Circuit</td>
<td>33</td>
</tr>
</tbody>
</table>
Whether your project requires new construction or retrofit, standard products or custom solutions, Shepherd Tower Components are a perfect fit.

· PVC Coated Hanger Grids
· Stainless Steel Hanger Grids
· Gull Wing Splash Fill Slats
· V-Bar Splash Fill Slats
· Film Pack
· Drift Reduction Units
· Nozzles & Accessories

C. E. Shepherd Company, L.P.
2221 Canada Dry Street
Houston, TX 77023
Telephone: 713.924.4300
Fax: 713.928.2324
www.ceshepherd.com
sales@ceshepherd.com

Since 1957, our primary business has been innovation!
We encourage inquiries for custom product solutions!
Just Introduced!

CTI Toolkit Version 3.1
...now Windows Vista and Windows 7 compatible

A great opportunity to upgrade your CTI Blue Book Version 1.0 and CTI Toolkit Version 2.0 Software

Key Features of CTI Toolkit Version 3.1:

- **Air Properties Calculator**: fully ASHRAE Compliant psychrometrics. Interactive.
- **Thermal Design Worksheet** in the “Demand Curve” Tab which can be saved to file and retrieved for later review. Now with printable and exportable graphs.
- **Performance Evaluator** in the “Performance Curve” Tab to evaluate induced draft or forced draft, crossflow or counterflow cooling tower performance. Now calculates percent performance or leaving water temperature deviation. Data can be entered manually or with an input file. Automatic Cross-Plotting. Now with printable and exportable graphs.
- **New and Improved Help Files** guide you through the software, explain performance evaluation techniques and offer tips for use.

Now works with Microsoft Windows 7 and all earlier Windows Operating Systems back to Windows 95
16 MB ram recommended, and 3 MB free disk space required.

*Upgrade Now!* Only $25/per upgrade from 3.0 for CTI Members ($40 for Non-Members)

To Order, Call (281) 583-4087 or visit CTI’s Website [www.cti.org](http://www.cti.org)
Order Today
Call 281-583-4087

“The Performance Curve method is widely recognized as a more accurate method of determining tower capability from measured test data. The new CTI ToolKit Tab Application provides a quick and easy method for anyone to evaluate a performance test using this more accurate method.”
- Rich Harrison, Jr.  ATC-105 Task Group Chairman

Bill to:

__________________________________________________________
__________________________________________________________
__________________________________________________________
__________________________________________________________

Air Properties Calculator

Fax: ____________________________

Ship to:

__________________________________________________________
__________________________________________________________
__________________________________________________________
__________________________________________________________

Phone: ____________________________ Fax: ____________________________

Email Address: ____________________________

<table>
<thead>
<tr>
<th>Product</th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTI ToolKit Version 3.1 (single user license)</td>
<td>CTI Member $395</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-member $450</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTI ToolKit Version 3.1 (Upgrade from V1.0 and V2.0)</td>
<td>CTI Member $95</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-member $120</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CTI ToolKit Version 3.1 (Upgrade from V3.0)</td>
<td>CTI Member $25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-member $40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PerfCurv 3.1 (Stand alone Performance Curve application)</td>
<td>CTI Member $195</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non-member $240</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Shipping for CD-Rom (from Texas):
Priority mail $6; 2nd Day Air $18; Overnight Domestic $28; International (DHL) TBA

Multi-user site licenses and educational institution pricing available on request

System Requirements:
Microsoft Windows® 95/98, 2000, XP, Vista and Windows 7

Phone: 281.583.4087
Fax: 281.537.1721
Web: http://www.cti.org
Index of Advertisers

TPI Tower Performance, Inc.
Cooling Tower Specialists

Since 1964, Tower Performance, Inc., has been providing full service to the utility, cogeneration, chemical, petrochemical and related industries by constructing new cooling towers and upgrading and repairing all makes and models of existing cooling towers.

New Cooling Towers
- Counterflow • Crossflow
- Wood • Steel • Concrete

Professional Services Include:
- Cooling Tower Evaluations
- Bid Preparations • Wood Analysis
- Thermal Engineering

Field Services Include:
- Repair & Overhaul
- Scheduled Maintenance
- Inspection & Evaluations
- Emergency Service

Nationwide Service

New Jersey Office:
- Toll Free: (800) 631-1196
- NJ: (973) 966-1116
- NY: (212) 355-0746
- Fax: (973) 966-5122
- E-Mail: ctowers@tpict.com

湖北 Office:
- Ph: (504) 346-7786
- Fax: (504) 293-7461
- E-Mail: ctowers@tpila.com

Louisiana Office:
- Ph: (970) 593-8637
- Fax: (970) 472-1304
- E-Mail: jfritz@towerperformance.com

Parts Sales:
- Toll Free: (800) 314-1695
- Ph: (970) 593-8637
- Fax: (970) 472-1304
- E-Mail: jfritz@towerperformance.com

Composite Cooling Solutions, LP
Gaiennie Lumber Company
GEA Polacel Cooling Towers LLC
Glocon
Howden Cooling Fans
Hudson Products Corporation
IMI Sensors a PCP Piezotronics Div
Industrial Cooling Towers
Innovex
International Chimney
Kemrock Industries
KIMCO
McHale & Associates
Midwest Towers, Inc.
Moore Fans
Paltech
Paharphur Cooling Towers
Power Gen
Research Cottrell Cooling
Rexnord Industries
C.E. Shepherd Company, LP
Simpson Strong-Tie
Spraying Services, Inc.
SPX Cooling Technologies
Strongwell
Tower Performance, Inc.
Turbo Machinery
Walchem
Walter P Moore
Zincobre Ingenieria, SLU

Advance (India) 63
Aggreko Cooling Tower Services 50-51
AIHR Expo 75
Amarillo Gear Company IBC
Amcot Cooling Tower 47
American Cooling Tower, Inc. 45
AMSA, Inc. 11
Bailsco Blades & Casting, Inc. 89
Baldor Electric Company 21
Baltimore Aircoil Company OBC
Bedford Reinforced Plastics 49
Brentwood Industries 53
BWA Water Additives 13
Cenck 19
ChemAqua 4
ChemTreat, Inc. 29
CleanAir Engineering 73
CTI Certified Towers 92-96
CTI License Testing Agencies 91
CTI Table Tops Exhibit 13
CTI ToolKit 98-99
Composite Cooling Solutions, LP 23
Cooling Tower Resources 55
Dynamic Fabricators 33
Fans Cooling Technologies 43
Fuel Ethanol 87
Gaiennie Lumber Company 6
GEA Polacel Cooling Towers LLC 9
Glocon 3
Howden Cooling Fans 5
Hudson Products Corporation 15
IMI Sensors a PCP Piezotronics Div 37
Industrial Cooling Towers IFC, 2
Innovex 61
International Chimney 85
Kemrock Industries 17
KIMCO 25
McHale & Associates 39
Midwest Towers, Inc. 35
Moore Fans 83
Paltech 59
Paharphur Cooling Towers 71
Power Gen 77
Research Cottrell Cooling 42
Rexnord Industries 67
C.E. Shepherd Company, LP 97
Simpson Strong-Tie 90
Spraying Services, Inc. 27
SPX Cooling Technologies 31
Strongwell 65
Tower Performance, Inc. 100
Turbo Machinery 79
Walchem 41
Walter P Moore 69
Zincobre Ingenieria, SLU 57
When you choose to work with an original like Amarillo Gear Company, you receive a lot more than the best product.

You work directly with the professionals who engineered that product in the first place and who have tested it, proved it and improved it over nearly 25 years of first hand field experience.

You gain access to a large staff of engineers who have years of experience trouble-shooting in unusual climates, conditions and unique applications.

You enjoy the security of knowing your warranty is backed by a company that will be around tomorrow with quick turnaround on the parts or service you require.

Amarillo Gear Company manufactures the world's most extensive line of right angle spiral bevel cooling tower fan drives available today, including single and double-reduction models and the new A Series of drives. Contact our staff of sales engineers for quick response to your cooling tower fan drive needs.
Baltimore Aircoil Company has redesigned the FXV closed circuit cooling tower. It will be exposed in Vegas at the AHR Expo January 2011

For more information go to www.baltimoreaircoil.com/FXV2011