Cooling Tower Operation and Maintenance is the Key for Improved Energy Efficiency
Cooling Tower Operation and Maintenance is the Key for Improved Energy Efficiency

Principle of Operation and Layout – Kavita Anuje
Maintenance Regimens – Trevor Hegg
Operating Strategies & Water Treatment - Paul Lindahl
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

Terminology

Open Cooling Towers
- Forced Draft Counterflow

Closed Circuit Cooling Towers
- Induced Draft Counterflow
- Forced Draft Crossflow
- Induced Draft Crossflow
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

**Open Cooling Tower**

An evaporative piece of equipment that exposes water directly to the cooling atmosphere, thereby transferring the source heat load directly to the air.
Closed Circuit Cooling Tower

An evaporative piece of equipment that contains two separate fluid circuits. The first is an external circuit where water is exposed to the atmosphere as it cascades over the tubes of a coil bundle. The second is an internal circuit in which the fluid to be cooled circulates inside the tubes of the coil bundle.
Forced Draft

Type of mechanical draft tower in which one or more fans are located at the air inlet to force air into the cooling tower.
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**Induced Draft**
Type of mechanical draft tower in which one or more fans are located in the air outlet to induce air through the air inlets.
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**Counterflow**

In a counterflow cooling tower, the air enters at the base of the tower, flows upward and interfaces counter currently with the falling hot water.
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**Crossflow**

In a crossflow cooling tower, the air flows horizontally through the cooling tower and interfaces perpendicularly with the falling hot water.
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Air Flow Direction

Water Flow Direction

Fluid Inlet

Fluid Outlet
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Air Flow Direction

Water Flow Direction
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- Air Flow Direction
- Water Flow Direction
- Fluid Inlet
- Fluid Outlet
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Air Flow Direction

Water Flow Direction
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Air Flow Direction

Water Flow Direction
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**Air Flow Direction**

**Water Flow Direction**
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- Water Distribution Systems
  - Gravity distribution system
  - Spray distribution system
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- Gravity Distribution System
  - Open basins
  - Large orifice, 360° nozzles
  - Easily accessed for maintenance
  - Basin water level used to balance flow
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- **Spray Distribution System**
  - Pressurized system
  - Large orifice, 180° directional nozzles
  - Spray header and branches
  - 2 PSI spray pressure at the header inlet
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- Heat Transfer Surface (Fill or Wet Deck)
  - PVC wet deck surface
  - Specialty wet deck materials
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- PVC Wet Deck Surface
  - Impervious to rot, decay, fungus and biological attack
  - 130°F limitation for counterflow cooling towers
  - 120°F limitation for crossflow cooling towers
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- High Temperature PVC Wet Deck Surface
  - Impervious to rot, decay, fungus and biological attack
  - 150°F limitation for counterflow cooling towers
  - 135°F limitation for crossflow cooling towers
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- Specialty Wet Deck Surfaces
  - Available for process type applications
    - Galvanized or stainless steel wet deck surface
  - Dirty water fill
  - Splash fill
  - Contact equipment manufacturer for performance information
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- Air Moving Systems
  - Axial fans
  - Centrifugal fans
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- Axial Fans
  - Over 80% of cooling towers on HVAC applications use axial fans
  - High volume/ Low static pressure
  - High efficiency
  - Low energy consumption
  - Improved sound ratings
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- **Centrifugal Fans**
  - High volume/Static pressures
    - Indoor installations
    - Inlet or discharge ductwork
  - High energy consumption
  - Quiet operation
  - Tight layout requirements
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- 1,500 GPM of Water
- 95°F EWT
- 85°F LWT
- 78°F EWB
- Counterflow, centrifugal fan unit requires 60 HP
- Crossflow, axial fan unit requires 30 HP
- Axial fan units require less HP than centrifugal fan units
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- **Drive Systems**
  - Belt drive
  - Gear drive
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- Proven performance on cooling tower application
- Efficient and designed for moist air applications
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

Cooling Tower Equipment Layout
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- Prevent warm air or drift from being introduced into fresh air intakes or from being carried over populated areas
- Consider the potential for plume
- Note the direction of the prevailing winds
- Ensure adequate supply of fresh air to the air intake
- Provide adequate space for piping and proper servicing and maintenance
- Top of the unit discharge must be at least level with the adjacent wall
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- Layout Examples
  - Adjacent to a wall or building
  - In an enclosure
  - Adjacent to a louvered or slotted wall
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- **Nominal**
  - 1,500 GPM 95/85/78

- **1°F Recirculation**
  - 1,384 GPM 95/85/79
  - 8% Derate

- **2°F Recirculation**
  - 1,258 GPM 95/85/80
  - 19% Derate
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- Nominal
  - 1,500 GPM 95/85/78
- 1°F Recirculation
  - 1,500 GPM 95.77/85.77/79
- 2°F Recirculation
  - 1,500 GPM 96.56/886.56/80
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

Every 1°F Increase in CWT Corresponds to a 2% Decrease in Chiller Efficiency
Correct cooling tower installation when located adjacent to a building or wall.
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- What is the distance between the wall and the air inlet to the cooling tower?
  - Maximum air velocity should not exceed 300 FPM
  - Air entry envelope consists of top and two sides
  - Based on 125,900 CFM, an inlet height of 10 feet and an air inlet length of 12 feet, the distance to the wall is 6.5 feet
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- When cooling towers are positioned with air inlets facing each other, the distance between cooling towers is \( 2 \times D \).
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

- What is the distance between the wall and the air inlet to the cooling tower for a well enclosure?
  - Maximum air velocity should not exceed 400 FPM
  - Center the cooling tower within the enclosure for uniform air flow to the air inlets
  - Air entry is from the top only
  - Based on 125,900 CFM, an air entry area as indicated by the shaded area, the distance to the wall is 8 feet
What is the distance between the louvered wall and the air inlet to the cooling tower for a well enclosure?

- Center the cooling tower within the enclosure for uniform air flow to the air inlets
- Louver must provide at least 50% net free area
- Louver air velocity should not exceed 600 FPM
- Maintain at least 3 feet between the tower air inlets and the louvered wall
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

Maintenance Regimens – Trevor Hegg
Maintenance Guidelines for Open Cooling Towers & Closed Circuit Cooling Towers
Maintenance and water treatment are the most important factors affecting the life and energy efficient operation of evaporative cooling equipment!
MAINTENANCE? Who needs it?
Maintenance and water treatment are the most neglected regimens of cooling tower operation, and cooling towers are generally the most neglected components in the mechanical system.

Why?

- Remotely located & difficult to access
- Limited maintenance resources
  - People
  - Training
  - Budgets
MAINTENANCE

Objectives:

• Review basic elements of a good maintenance regimen.

• Develop an understanding of the costs of poor maintenance on the life & energy efficiency of cooling towers.
MAINTENANCE REGIMENS

Review major cooling tower systems and their appropriate maintenance regimens:

- Circulating Water
- Fan and Drive
- Heat Transfer Surface (Fill or Coil)
- Air Entry Louvers
- Drift Eliminators
MAINTENANCE REGIMENS

- Reputable manufacturers provide maintenance instructions and check sheets. It is best to follow the manufacturer’s recommendations!
- ASHRAE Handbook also provides a good general guide.
• Manufacturer and ASHRAE guidelines are for normal cooling season regimens.
• Unusual operating conditions will require additional operator attention.
• Winter operation and long-term shut-down requires additional servicing. Consult the manufacturer.
MAINTENANCE REGIMEN –
Circulating Water System Types

Cross-flow Tower Operation    View of Water Distribution Box

Gravity Flow Water Distribution System
Common to cross-flow cooling towers and coolers.
MAINTENANCE REGIMEN –
Circulating Water System Types

Closed Circuit Tower Operation

View of Pressurized Distribution System and Nozzles

Pressurized Flow Water Distribution System
MAINTENANCE REGIMEN – Circulating Water System

Spray Nozzles & Water Distribution Boxes need to be inspected & cleaned
- After start-up and
- Monthly thereafter.

Regular inspection allows quick treatment and control of corrosion and mechanical failures.
MAINTENANCE REGIMEN – Circulating Water System

Clogged distribution nozzles cause:

- Reduced or mal-distributed water flow = capacity reduction
- Heat Exchanger surface scaling/fouling = capacity reduction
- Overflowing distribution boxes = water & chemical loss
- Excessive drift = water & chemical loss
- Fan motor over-amping (forced draft) = reduced motor life
MAINTENANCE REGIMEN – Circulating Water System

Suction Strainers:

- Designed to protect pump and nozzles.
- Inspect & clean weekly.
- Operating environments laden with airborne fibrous materials (agricultural, paper, textile processing) demand more frequent strainer cleaning.
MAINTENANCE REGIMEN – Circulating Water System

Poor Strainer maintenance leads to:
• Reduced flow = reduced capacity
• Pump cavitation = pump repair costs and objectionable plant noise
• Collapsed strainers = tower repair costs
MAINTENANCE REGIMEN – Circulating Water System

Basin Maintenance:

- Clean and flush monthly.
- Inspect and repair corrosion.

Accumulated solids:

- Clog equalizer & bypass lines
- Hide corrosion cells
- Give breeding environment for bio-growth
MAINTENANCE REGIMEN – Circulating Water System

Closed Circuit Tower Water Pumps:

- Inspect seals & free rotation of shaft monthly.
- Lubricate bearings per motor manufacturer instructions.

Leaking seals are costly with lost water and treatment chemicals.
MAINTENANCE REGIMEN – Circulating Water System

Make-up water and operating level controls

Mechanical Float Valve      Electric Valve & Sensor

Mechanical Float Valve      Electric Valve & Sensor
MAINTENANCE REGIMEN –
Circulating Water System

Set operating level and water supply pressure to manufacturer’s recommendations.

- Inspect water level and adjust float monthly.
- Inspect valve seals and full shut-off monthly.

Clean electronic sensing elements as required!
MAINTENANCE REGIMEN – Circulating Water System

Malfunctioning level control can be costly with water and chemical loss and even equipment damage.

Proper water level control is required for pump priming and prevention of air entrainment in suction lines.
MAINTENANCE REGIMEN – Fan & Drive System

The fan system moves the air which cools the water. **It is critical to keep the fan system in top operating condition!**

- Daily walk around the tower and listen for unusual noises or vibration.
- If reasons for vibration are easily detected, (loose belts, loose motor base, loose bearing locking collars, loose fan or sheave bushings) correct as required.
- If causes of vibration are not easily detected, consult a specialty vibration analysis contractor.
MAINTENANCE REGIMEN – Fan & Drive System

- Quarterly clean fan of heavy debris (trash, bird droppings, scale) and inspect the fan and drive components for tight fasteners, missing balance washers & structural integrity.
- Repair or replace corroded hardware, even the fan if necessary.
- Check the mechanical equipment support for cracks and tight hardware.
- Check security of fan guards.
Belt Drive Systems:

**Belt Tensioning:**

Check 24 hrs after start-up.

Check monthly thereafter.

1/2” - 3/4” deflection with moderate finger pressure at center span of belt. Check manufacturer’s O&M guide.
Gear Drive Systems:

**Lubrication:**
Check oil level weekly. Change oil 500 hours or 4 weeks after start-up. Follow gear box O&M guide for oil type and change frequency. Recommend synthetic, oxidation inhibited oil.
MAINTENANCE REGIMEN – Fan & Drive System

Gear Drive Systems:

- Inspect drive shaft and coupling hardware monthly.
- Inspect coupling flex elements for buckling and fatigue damage. Replace as required.

Drive Shafts:

Drive shaft Coupling
MAINTENANCE REGIMEN – Fan & Drive System

Fan Shaft Bearings:

**Bearing Lubrication:**

**Lubrication Schedule**

- 1000 hours or 3 months
  ---- Induced Draft

- 2000 hours or 6 months
  ---- Forced Draft

- Use water resistant grease approved by manufacturer.
MAINTENANCE REGIMEN – Fan & Drive System

Motors:
Good maintenance starts with the installation

1. Wire per nameplate and check rotation
   • Multi-lead (9, 12 wire) motors may be confusing
   • Check multi-speed motor rotation at both speeds
   • Check current draw on start-up

2. Check operational controls
   • Set proper time delay between speed changes
   • Set thermostat differentials to limit fan cycling
     (3-6 starts/hour)
MAINTENANCE REGIMEN – Fan & Drive System

Motors:
Motor life and efficiency is enhanced by

1. Keeping motor body cool
   - Clean casing and cooling fins of scale build-up
   - Do not obstruct cooling vents around motor

2. Properly lubricating motor bearings
   - Follow motor O&M guide for lubrication intervals, typically 2-3 years, and compatible greases.
   - Some motors have sealed bearings and do not require lubrication.
MAINTENANCE REGIMEN – Fan & Drive System

Motors:
Motors driven by variable frequency drives (vfd)

1. Offer fan energy saving at the cooling tower
2. Reduce fan cycling and provide soft starting
3. Need to be specifically selected for vfd duty
4. Need limits on length between motor & drive
   (Depending on drive, typically 50 to 200 feet.)
5. Run hotter and need good cooling air-flow
MAINTENANCE REGIMEN – Heat Transfer Surface

Inspect heat transfer surfaces monthly. Inspect both the top and bottom. Generally, scaling starts on the top and bio-fouling builds from the bottom.
MAINTENANCE REGIMEN – Heat Transfer Surface

Open Tower Packing (Fill):

• Scale, solids and bio-fouling restrict air & water passages.
• Capacity diminishes rapidly with increased fouling.
• Extra weight can damage fill and structural supports.

Typical fill clogging from bio-films and suspended solids.
MAINTENANCE REGIMEN –
Heat Transfer Surface

Closed Circuit Tower Coil:

• Scale on coil walls is a direct heat transfer barrier.
• Capacity diminishes with increased fouling.
MAINTENANCE REGIMEN – Heat Transfer Surface

Closed Circuit Cooling Tower Performance vs. Scale Accumulation on Heat Transfer Coil

- **Clean Tube**: 100.0%
- **1/32" Scale (0.8 mm)**: 90.0%
- **1/16" Scale (1.6 mm)**: 80.0%
- **3/32" Scale (2.4 mm)**: 70.0%

Fouling Factor & Approximate Scale Thickness On Coil

Closed Circuit Tower Coil
MAINTENANCE REGIMEN – Heat Transfer Surface

Cleaning heavy scale or bio-fouling is difficult. Often the fill or coil are damaged in the process.

Results of a scaled coil cleaned with acid. This coil is ruined.

IT IS ESSENTIAL TO MAINTAIN A PREVENTATIVE WATER TREATMENT PROGRAM.
MAINTENANCE REGIMEN –
Drift Eliminators

Separate water droplets from leaving air stream
- Subject to damage from weather & vandalism
- Subject to corrosion

Damaged eliminator section, which should be replaced.
MAINTENANCE REGIMEN – Drift Eliminators

Proper placement and good physical condition
• Minimizes water and treatment chemical loss
• Minimizes air restriction for maximum capacity
• Minimizes airborne bacterial transmission

➤ Inspect condition and placement monthly.
➤ Replace damaged eliminators.
Examples of scaled, bio-fouled and debris laden inlet louvers.
MAINTENANCE REGIMEN – Air Inlet Louvers

Proper placement and good physical condition

- Minimizes water and treatment chemical loss from basin splash-out.
- Minimizes air restriction for maximum capacity
- Minimizes airborne bacterial transmission

- Inspect condition and placement monthly.
- Repair damaged louvers.
Winter Operation
Maintenance & Energy Saving Tips

Prevent freezing and expensive ice damage before the winter season arrives:

- Check heat tracing and insulation on drains, make-up and circulating water lines.
- Test basin heaters and controls.
- Charge coils with glycol or drain completely.
- Test operation of positive closure dampers - open with fan on and closed with fan off.
Winter Operation
Maintenance & Energy Saving Tips

More tips:

- Do not run fans with pumps off unless basin is drained.
- Ensure that fan drives are selected for dry operation.
- Interlock heater “off” when pump or fan operates.
- Keep a heat load on the tower. Cold water temperature should stay above 40°F (4.4°C)
Winter Operation
Maintenance & Energy Saving Tips

Ice can cause expensive damage to the fill and tower structure.

- Schedule regular defrost cycles.
- Keep water flow in safe range of the distribution nozzle.
Towers lacking a good maintenance regimen, which includes water treatment, routinely operate at well below design capability.

A basic maintenance regimen is an investment to:

- maximize the energy efficiency of the tower and the mechanical system,
- minimize capital investment in equipment by extending its life and replacement intervals,
- minimize annual maintenance expenses through preventative measures rather than costly repairs.
Cooling Tower Operation and Maintenance for Improved Energy Efficiency

Operating Strategies and Water Treatment

Paul Lindahl
WHY WATER TREATMENT?

Air and water contents enter and build in the tower.
Biological Growth

- **Bacteria, Algae**
  - Fouling exchangers
  - Fouling Cooling Tower
  - Health Effects, such as Legionnaire’s Disease

- **Water Treatments**
  - Oxidizing Biocides
  - Non-oxidizing Biocides

- **Deposits assist growth of biofilms and biofouling, side stream filtration is recommended**
Corrosion

- Consider metals in entire water system
  - Steel and Iron vs. Stainless Steel
  - Copper and its Alloys
  - Aluminum
- Appropriate Water Treatments with qualified WT vendor/consultant
- Control deposition of solids, side stream filtration recommended
Deposits Impact Corrosion

Oxide Layer

CELL METABOLISM LOWERS pH UNDER BIOFILM WHICH CORRODES METAL
Deposits Impact Corrosion

Oxide Layer

PITTING FAILURE
Each Treatment Impacts the Others

MICROBES (MB)

CORROSION  DEPOSITION
Control Methods

- **Biocide** to reduce Microbe and Biofilm Growth [corrosion and scaling effect]
- **Inhibitors** to protect Metals from Corrosion
- **Inhibitors** to prevent Scale Precipitation

- **Surfactant** = Bio-penetration
- **Anti-foam** = Reduce visible effect of biocide
Water Quality

General Guidelines:

Note: for tower water, not make-up

- High Temperature: < 120 °F
- PH: 6.5 – 9.0
- Chlorides: < 750 ppm for Galvanized Steel, < 1500 ppm for 300 Series Stainless Steel
- Calcium: (as CaCO3) < 800 ppm should not result in calcium sulfate scale
Sulfates: If calcium > 800 ppm, sulfates < 800 ppm (or less in arid climates) to limit scale.

- Otherwise, < 5000 ppm is acceptable.

- Silica: < 150 ppm as SiO2 to prevent silica scale

- Iron: < 3 ppm

- Manganese: < 0.1 ppm
Water Quality

- **Total Suspended Solids (TSS):**  
  - < 25 ppm for film fill

- **Total Dissolved Solids (TDS):**  
  - < 5000 ppm for thermal performance

- **Oil and Grease:**  
  - Avoid with film fill (contributes to fill plugging, prevents proper seasoning).

- **Ammonia:**  
  - Limit to 50 ppm if copper alloys are present
Water Quality

- Combinations of treatment chemicals may cause reactions which reduce treatment effectiveness.
- Certain chemicals such as surfactants, biodispersants and antifoams may increase drift rate.
- Consult CT & WT vendors/consultants.
Concentrations and Blowdown

- Evaporating water leaves minerals, concentrates over time
- Blowdown of a small amount of water keeps concentration at desired level
- \[ C = \frac{R \times EPD + BD + D}{BD + D} \]
Concentrations and Blowdown

Example:

- Evaporation = 0.08% circulating water per degree of range
- Drift = 0.02% of circulating water rate
- Range = 10 Deg F
- Concentrations = 5
- Blowdown = 0.18% of circulating water rate
## Concentrations and Blowdown

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Based on: 0.02% drift rate and 0.08% evaporation rate
Operation for System Efficiency
Condensing Water Temperature

- 3 GPM/TR (95°/85°/78°)
- 2 GPM/TR (105°/85°/78°)
- Lower condensing temperatures, fans full, gives coldest water at chiller
- Chiller energy savings almost always outweighs tower fan energy consumption

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DESIGN COOLING TOWER FAN HP VARIATION

FAN HP PER TON OF LOAD

(BASIS: 75°F WET-BULB)
Capacity Control Methodologies

- Capacity Control Dampers
- Multi-speed Motors
- Variable Frequency Drives
- Single Speed Fan Cycling
- Free Cooling
- Fans full Speed – Run Wild
Capacity Control Dampers

- Offers precise system control
- No fan power savings
Effect of Fan Speed on Capacity

FAN CHARACTERISTICS
CAPACITY & HORSEPOWER RELATIVE TO SPEED

PERCENT OF DESIGN FAN SPEED

CAPACITY (AIRFLOW)  REQUIRED POWER
Single Speed, Full Power

TYPICAL COOLING TOWER PERFORMANCE
SINGLE CELL TOWER — SINGLE SPEED FAN

COLD WATER

WET BULB TEMPERATURE — (°F)

10°F RANGE
Two Speed

TYPICAL COOLING TOWER PERFORMANCE

SINGLE CELL TOWER — TWO SPEED FAN

(COLD WATER) vs. WET BULB TEMPERATURE — (°F)

(10°F RANGE)

FULL SPEED

HALF SPEED
Two Cell, Two Speed

TYPICAL COOLING TOWER PERFORMANCE
TWO CELL TOWER — TWO SPEED FANS

COLD WATER

WET BULB TEMPERATURE — (°F)

(10°F RANGE)

- FULL SPEED
- 1 HALF, 1 FULL
- HALF SPEED
Variable Frequency Drive Fan Control
Compressor Impact

TYPICAL COOLING TOWER PERFORMANCE
SINGLE CELL TOWER — SINGLE SPEED FAN

Region for influencing compressor horsepower.
Compressor Power

POTENTIAL COMPRESSOR HP REDUCTIONS
CONSTANT LOAD — REDUCING CONDENSER WATER TEMPERATURE

This is a “rule of thumb” curve. Verify actual reductions with chiller manufacturer.
Free Cooling Region

TYPICAL COOLING TOWER PERFORMANCE
SINGLE CELL TOWER — SINGLE SPEED FAN

- Region for consideration of “free cooling”.

10°F RANGE
“Free Cooling”

• When the tower can produce sufficiently cold water without the chiller.
  • Direct free cooling..
  • Indirect free cooling..
Free Cooling Operation

Graph assumes that the system will go to free cooling when the tower is capable of producing 50°F or colder water.

Typical Cooling Tower Performance

Full Load — Full Fan Speed — Full Water Flow

Cold Water Temperature — (°F)

Wet Bulb Temperature — (°F)

Chiller On

Chiller Off
Benefit Depends on Location

WET BULB OCCURRENCE
DES MOINES VICINITY

ANNUAL HOURS INDICATED W.B. WILL NOT BE EXCEEDED
Cooling Tower Operation and Maintenance for Improved Energy Efficiency