evapco ENGINEERING BULLETIN No. EB 023A

Product: Cooling Towers Date: August 1993

Open Cooling Tower
Free Cooling Operation

Winter operation of cooling towers can prove to be effective in lowering the operating costs of cooling systems in cold winter months. EVAPCO's counterflow cooling towers are well-suited to cold weather operation. However, this type of application requires several precautionary measures to ensure the reliable operation of the cooling tower.

When operating a cooling tower in subfreezing conditions there is always the potential to produce ice somewhere in the system. It is important to have the ability to keep ice formation under control so that it doesn't affect the capacity of the tower, damage the tower, or cause a hazard to the building or its occupants. This is the object of our efforts….to recognize the potential for ice build up and to be able to manage it effectively. In this bulletin we will present techniques and recommendations that will help to provide successful management of counterflow cooling towers operating in subfreezing temperatures.

"Standard" cooling tower operation provides leaving water temperatures of 65-85°F. This type of winter operation presents relatively little danger of damaging ice build up. The potential for ice formation increases substantially when cooling towers are used to provide "chilled water" temperatures for 45-55°F which is commonly known as "free cooling". <u>We recommend contacting the EVAPCO Marketing Department when utilizing an EVAPCO cooling tower for free cooling operation.</u>

Free cooling operation at low leaving water temperatures in subfreezing ambient conditions is more prone to ice formation than winter operation at higher leaving water temperatures. If the wrong tower design is chosen, or if the unit is not operated or winterized properly, excessive ice formation can result. This formation can cause extreme operational difficulties.

Cooling tower performance in free cooling applications is dependent upon both the system and cooling tower design configuration. The control sequence applied to these design elements must consider the control of both the air and water in the cooling system. This bulletin will examine various methods of cooling tower design and controls required to ensure proper system operation for free cooling applications.

Layout

Careful consideration must be given to the proper location and layout of cooling towers on each project. Adequate unobstructed air flow must be provided for both the intake and discharge of the tower. While recirculation can dramatically reduce capacity in summer operation, recirculation during winter operation can result in condensate freezing on inlet louvers, fans, fan shafts, and fan screens and thus obstruct air flow. Further, poor layout conditions can cause downward air flow through the tower when the fans are not operating. This situation promotes ice formation on inlet louvers of induced draft models and on the fans of forced draft models.

Cooling tower performance can also be affected by prevailing winds. High winds can create icing conditions on inlet louvers and fan screens and therefore affect air flow as described above.

Lastly, building vents and air intakes can substantially affect tower performance. Consideration should also be give to ensure that the discharge air from the cooling tower is not directed into a building vent or intake louver. These situations should be referred to the EVAPCO Marketing Department for analysis.

For more details on cooling tower layouts, please refer to the EVAPCO Layout Bulletin.

Capacity Control and Ice Management

It is very important to maintain close control on the cooling tower during winter operation. Laboratory testing and experience has shown that 42°F should serve as the absolute minimum leaving water temperature. In order to provide a margin of safety, EVAPCO normally recommends a minimum leaving water temperature of 45°F. Generally, the higher the leaving water temperature the lower the chance of ice formation; assuming adequate water flow is maintained and proper fan control procedures are followed.

The sequence of control for a cooling tower operating under free cooling conditions is much the same as a cooling tower operating under summer conditions if the ambient conditions are above freezing. When the weather becomes very cold additional precautions must be taken to avoid dangerous ice formation.

Each type of cooling tower requires separate rules for capacity control and ice management for free cooling in cold weather. We have developed schemes for both induced and forced draft cooling towers and will examine each in turn.

Regardless of what type of capacity control is utilized, a full flow bypass may be required. If the cooling load is to be maintained below 30% of the full winter capacity, then a full flow bypass valve should be incorporated. This valve serves to divert water from the tower water distribution system. Bypass water flow can be directed to the tower basin or incorporated into the system piping. Whichever style of bypass configuration is utilized, **partial flow bypass can create dangerous ice build up and is never recommended!**

Attached to this bulletin are recommend control sequences for cooling towers operating under free cooling conditions. Below is a summary of capacity control options for each type of product.

Induced Draft Models

Capacity control of induced draft cooling towers can be achieved by a number of methods. Two of the more common methods are two-speed fan motor control and variable frequency speed controllers. It is important to check with EVAPCO's Marketing Department prior to proceeding with variable frequency control for induced draft towers to ensure that critical fan speeds are avoided. See attached performance data for each model.

The application of a variable frequency controller to an induced draft cooling tower can contribute to ice formation in subfreezing temperatures. As heat load requirements are reduced, the variable frequency control system may operate for long periods of time at fan speeds below 50%.

Operating at continuous low air velocity and low leaving water temperature may allow ice to begin to form at various points inside the cooling tower during winter operation. It is therefore recommend that the minimum speed of the variable frequency controller be set at 50% of full speed. Setting the minimum speed at 50% forces large changes in operating conditions which minimizes the opportunity for ice build up.

Off-cycling fan motors to control capacity is a viable step of control for induced draft towers. It also is an important step in ice build up control. During these periods the water flows over the tower to help melt any ice formed in the basin or louver area while the fan is turned off.

Another means to manage ice formation is the incorporation of "defrost" cycles. During these periods of operation, the fans are reversed at half speed while the system pump flows water through the tower distribution system. This process requires the use of two speed motors or a variable frequency controller with reverse cycle starters. Defrost cycles should be incorporated into the normal control schematic of the tower operation. Inspect the tower regularly to determine the length and frequency of defrost cycles. Excessive ice formation should be avoided between "defrost" cycles as falling ice can become a dangerous hazard to the building and its occupants.

Forced Draft Models

Forced drafts models require special care during free cooling operation in sub-freezing temperatures. When the fans are cycled off for capacity control, the water falling through the tower can induce air flow through the fan section. This moist air may condense and freeze on the cold fan parts allowing ice to build on the fan system. Fans should be cycled during cold weather operation to avoid long periods of idle fan operation. Proper control of the fans will prevent ice formation and provide the necessary capacity control for system operation.

Capacity control of forced draft cooling towers may be achieved by a number of methods. The simplest method used is that of cycling the fan motor on and off in response to the tower leaving water temperature, however, fan cycling alone does result in larger temperature differentials and extended periods of time with fans off. The addition of fan dampers and controls can be used to reduce the temperature differentials and periods of time with fans off. However, fan dampers and controls will normally require more maintenance than other control systems and may become increasingly difficult to manage as ambient conditions and system operating temperatures are reduced.

Two speed motors are often a preferred method for capacity control. This type of fan cycling offers and additional step of capacity control which will both reduce temperature differentials in the system and minimize the amount of time which the fans will remain off. Additionally, two speed motors provide a substantial savings in energy costs. This method of capacity control has proven effective for systems which provide a constant load and are operating in relatively moderate winter conditions.

Variable frequency drives are becoming increasingly popular for forced draft equipment required to operate under free cooling conditions. The VFD control system allows the fans to run at a nearly infinite range of speeds to match the unit capacity to the system load. During periods of reduced load and low ambient temperatures, the fans can be maintained at a minimum speed which will ensure positive air flow through the tower. Since extended periods of down time are eliminated, moisture cannot condense on the fans and freezing problems in this key area are eliminated.

Defrost cycles are normally not recommended for forced draft cooling towers. Since icing problems can occur when fans are cycled off for extended periods of time, the "Defrost Cycle" has been proven ineffective for this equipment design. Forced draft models may be operated successfully in "Free Cooling" applications by utilizing appropriate capacity control methods and following the general guidelines presented in this Engineering Bulletin.

Fan & Water Control: Multiple Cell Installation
Both induced and forced draft multiple cell units require modified control sequencing during free cooling operation. All fans in operating cells must be controlled simultaneously to avoid freeze-u[in any one cell. Since it is common to have only one sensor reading mixed leaving water temperature, and independent fan cycling can create an icing condition in the operating cell. This is true for any multiple cell tower installation. Also, it is strongly recommended that water temperature be sensed in all cells to provide an alarm for possible icing conditions in any individual cell.

Control over the water flow is also very important during winter operation of cooling towers. When loads drop off, reduced flow rates may result, thereby creating the possibility for ice build up. We recommended that the water flow rate be directed to as few tower cells as possible to maintain proper water distribution. In these situations, the idle cells must be completely valved off (isolated) from the operating cells.

Electronic Water Level Control
For units operating year round in a cold climate, use of the optional Electronic Water Level Control Package is recommended. This package replaces the standard mechanical make-up valve and float assembly thus eliminating the problem of ice formation and blockage of this component. It provides very accurate control of the basin water level and does not require field adjustment – even under widely varying operating conditions.

Vibration Cut-Out Switch
Another accessory useful in winter operation is a vibration cut-out switch. Should ice build up occur on the fan or fan parts, the resultant vibration would be detected before fan failure could occur.

Freeze Protection (Basin Water and External Piping)
All external piping that does not drain must be heat traced and insulted. This includes water circulation pumps, riser pipes, and any accessories (including the stand pipe associated with an optional electronic water level control package).

A remote sump located in an indoor heated space is an excellent way to prevent a problem with basin water freezing during idle or no load conditions. A second alternative would be to provide basin heaters that are designed to maintain the sump water temperature at 40^{o}F. It should be noted that sump heaters do not need to operate when there is a heat load and water is flowing through the tower. The basin heaters are normally electric but steam or hot water coils can be provided.

It should be noted that probes and sensing devices should be protected from damage from floating or falling ice. Installation of such devices in remote sump piping is not recommended.

Maintenance
The best way to aid cooling tower performance during winter operation is to ensure that the tower is in proper working order. The bearings should be lubricated as recommended and the belt should be tensioned properly. Please consult the Maintenance Checklist for other inspection criteria and their required frequency of inspection.

Frequent tower inspections are strongly recommended. At a minimum, one daily inspection should be done, and more frequent inspections are encouraged. Mornings are the most important time to conduct inspections. During these inspections, it is advisable to check the strainers for cleanliness, to check the basin water level, and to verify proper spray pattern form the water distribution system.

Other items to check on a less frequent basis are: the basin heaters and heat tracing to ensure that they are operative, the fan bearings and motors for proper lubrication, and the water quality to ensure it is within operating parameters.

Some ice formation inside the unit may occur but should not be of concern unless operating temperatures are affected. Normal defrost cycles should solve any ice build up problems, however, if operating problems arise, check the control sequence focusing the leaving water temperature. The leaving water temperature should never be allowed to drop below the control point.

On multiple cell installations, verify that the fans are controlled together. In the event that ice build up occurs on the inlet louvers of an induced draft tower, verify that the water flow is not in excess of the tower's maximum flow as shown in the EVAPCO catalog water loading curves. Conversely, if the water flow drops below the minimum water loading for a given tower cell and nozzle selection, ice may form below the tower fill in the center of the tower cell or around the side walls.

Summary
Low leaving water temperatures and cold ambient conditions increase the possibility of ice formation in a cooling system when using an open cooling tower to provide chilled water temperatures. The key to successful tower operation is system management. Careful consideration of layout conditions, model type, and control sequence is important to ensure proper tower operation.

Proper preventive maintenance and frequent tower inspection is also very important to tower operation. A lack of proper maintenance increases the risk of dangerous ice formation. By following the above operating guidelines and procedures, free cooling with an open cooling tower can be quite successful.

Please notify the EVAPCO Marketing Department when utilizing a tower for a free cooling for tips on cooling tower operation and control as well as possible tower modifications.

Two Speed Fan Motor Control Sequence
Induced Draft Models

System Off/No Load
System pumps and fans off. Basin heaters cycling as required to maintain water temperature.

System Temperature Rises
System pumps turn on, interlock in pump starter turns heaters off and tower supply valve is positioned to allow full water flow to tower basin bypassing tower water distribution system.

If the system temperature rises above minimum control point the tower supply valve is opened to allow full flow to the tower water distribution system

If the system temperature continues to rise, the tower fan motor is turned on to low speed. In multi-cell units, the fans in each operating cell are to be turned on low speed. ALL OPERATING CELLS MUST BE CONTROLLED TOGETHER!

If the system temperature continues to rise, then all operating fans are to be turned to high speed.

System Temperature Stabilizes
Continue to control the tower leaving water temperature by cycling fans between high and low speed. Allow for time delay when switching from high to low speed.

Scheduled Defrost Cycle
Periodically, all fans should be cycled off and then reversed at low speed to allow the system temperature to rise for a short period and control ice build up. Allow for time delay when reversing fans. Inspect tower regularly during sub-freezing temperatures to determine frequency and length of defrost cycles.

System Temperature Drops
If system temperature drops to minimum control point, turn the fans off.

If the system temperature continues to drop below the minimum control point, the tower supply bypass valve opens to allow full flow bypass.

System Off/No Load
System pump and tower fans off. Starter interlock energizes heater circuit.

NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42^{o}F.

Variable Speed Fan Motor Control Sequence
Induced Draft Models

System Off/No Load
System pumps and fans off. Basin heaters cycling as required to maintain water temperature.

System Temperature Rises
System pumps turn on, interlock in pump starter turn heaters off and tower supply valve is positioned to allow full water flow to tower basin bypassing tower water distribution system.

If the system temperature rises above the return water set point the tower supply valve is opened to allow full flow to the tower water distribution system.

If the system temperature continues to rise, the variable speed controller calls for minimum air flow from tower fans.

NOTE: ***During sub-freezing weather the minimum recommended speed for variable speed controllers is 50%***. ALL FANS IN OPERATING CELLS MUST BE CONTROLLED TOGETHER!

If they system temperature continues to rise, then all operating cell fans are increase fan speed as required up to 100%. Some models may require certain fan speeds to be locked out. Consult the chart attached for critical speeds.

System Temperature Stabilizes
Continue to control the tower leaving water temperature by modulating fan speeds between 50 to 100% fan speed.

Scheduled Defrost Cycle
Periodically, all fans should be cycled off and then reversed at 50% fan speed to allow the system temperature to rise and remove ice build up. Inspect tower regularly during sub-freezing temperatures to determine frequency and length of defrost cycles.

System Temperature Drops
Decrease fan speed as required down to 50%. If system temperature drops to minimum control point, turn the fan off.

If the system temperature drops below the minimum control point, the tower supply bypass valve opens to allow full flow bypass.

System Off/No Load
System pump turns off and starter interlock energizes heater circuit.

NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42^{o}F

Two Speed Fan Motor Control Sequence
Forced Draft Models

System Off/No Load
System pumps and fans off. Basin heaters cycling as required to maintain water temperature.

System Temperature Rises
System pumps turn on, interlock in pump starter turns heaters off and tower supply valve is positioned to allow full water flow to tower basin bypassing tower water distribution system.

If the system temperature rises above minimum control point the tower supply valve is opened to allow full flow to the tower water distribution system.

If the system temperature continues to rise, the tower fan motor is turned on to low speed. In multi-cell units, the fans in each operating cell are to be turned on low speed. ALL OPERATING CELLS MUST BE CONTROLLED TOGETHER!

If the system temperature continues to rise, then all operating fans are to be turned to high speed.

System Temperature Stabilizes
Continue to control the tower leaving water temperature by cycling fans between high and low speed. Allow for time delay when switching from high to low speed.

Scheduled Defrost Cycle
Periodically, all fans should be cycled off to allow the system temperature to rise for a short period and control ice build up. Inspect tower regularly during sub-freezing temperatures to determine frequency and length of defrost cycles.

Fans should not be idle for long periods of time while water is flowing to water distribution system as condensate can form dangerous ice build up on the fan.

System Temperature Drop
If system temperature drops to minimum control point, turn the fans off.

If the system temperature continues to drop below the minimum control point, the tower supply bypass valve opens to allow full flow bypass.

System Off/No Load
System pump and tower fans off. Starter interlock energizes heater circuit.

NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42^{o}F

Variable Speed Fan Motor Control Sequence
Forced Draft Models

System Off/No Load
System pumps and fans off. Basin heaters cycling as required to maintain water temperature

System Temperature Rises
System pumps turn on, interlock in pump starter turns heaters off and control valve is positioned to allow full water flow to tower basin bypassing tower water distribution system.

If the system temperature rises above the return water set point the control supply valve is opened to allow full flow to the tower water distribution system. Variable speed controller calls for minimum air flow from tower fans.

Note: ***During sub-freezing weather, forced draft models should have a minimum 10% fan speed whenever water is directed to tower water distribution system to avoid dangerous ice build up on fans***. ALL FANS IN OPERATING CELLS MUST BE CONTROLLED TOGETHER!

If the system temperature continues to rise, the variable speed controller increases tower fan speed as required up to 100%.

System Temperature Stabilizes
Continue to control the tower leaving water temperature by modulating fan speeds between 10 and 100% fan speed.

System Temperature Drops
Decrease fan speed as required to 10%

If system temperature drops to minimum control point, the tower supply bypass valve opens to allow full flow bypass to tower basin. Variable speed controller turns tower fans off.

System Off/No Load
System pump turns off and starter interlock energizes heater circuit.

NOTE: MIMINUM CONTROL PONT SHOULD NEVER BE LOWER THAN 42^{o}F

Variable Speed Performance
Induced Draft Models

A variable frequency drive used with an EVAPCO induced draft cooling tower may encounter critical fan speeds. Use the chart below as a guide to identify and lock out critical speeds from normal operation.

Model Number	***Fan Speeds to Avoid (% of Full Speed)***
ICT 3-63 thru ICT 4-912	None
AT 8-56B thru AT 8-99B	None
AT 8-012B thru 312B	None
AT 8-412B	77-94
AT 8-512B & 612B	None
AT 8-712B thru 912B	77-94
AT 8-318B thru 918B	None
AT 8-324B & 424B	None
AT 8-524B thru 924B	77-94
AT 8-536B	None
AT 8-636B thru 936B	77-94
AT 12-212B thru 512B	None
AT 12-612B	79-97
AT 12-712B & 812B	None
AT 12-912B	770-97
AT 12-218B & 418B	None
AT 12-318B, 518B & 618B	79-96
AT 12-718B thru 918B	77-94
AT 12-324B thru 724B	None
AT 12-824B & 924B	79-97
AT 12-136B, 236B, 436B	None
AT 12-336B, 536B, 636B	79-96
AT 12-736B thru 936B	77-94
AT 12-454B	None
AT 12-554B, 654B	79-96
AT 12-754B thru 954B	77-94
AT 24-218B, 418B	None
AT 24-318B, 518B, 618B	79-96
AT 24-718B thru 918B	77-94
AT 24-524B thru 824B	None
AT 24-924B	79-97
AT 24-336B thru 536B	None
AT 24-636B	79-96
AT 24-736B thru 936B	77-94

Tips for System Design for Cooling Towers Operating in Low Ambient Conditions

1. Early in the design phase you should discuss the load, flow rate, and temperature. Note that the winter load will be much smaller than the summer load, but may be much harder for the cooling tower to perform. Also the range will vary since the heart of compression no longer needs to be rejected. Typically, a free cooling application will operate on an 8 degree range.

   Under most conditions standard unit construction will perform satisfactorily, however, depending on the required temperatures and ambient conditions, modifications can be made to aid in free cooling operation. Contact the EVAPCO Marketing Department for available options.

2. Once the free cooling load has been established, the design conditions will be specified. Every attempt should be made to not specify terribly low leaving water temperatures. EVAPCO recommends a minimum leaving water temperature of 45^{o}F.

   Further, tower conditions need to be monitored closely. Extended period of unattended free cooling operation or remote control should be avoided.

3. Low flow conditions should be avoided. Flow rates should be as high as possible. Partial flow bypass should never be used. Ice formation is less likely when flow rates are high.

4. Cooling tower selection is very important. Although a large single cell may be a good selection, a smaller, multi-cell tower may be a better selection. At lower flow rates the load could be concentrated in fewer cells. This allows the flow rate per cell to remain as high as possible and less likely to form ice n the inlet louvers.

   Multi-cell towers also provide backup capacity in case of a failure in an operating cell. Leaving water temperatures should be sensed in all cells of a multi-cell unit. If the temperature of the water leaving any particular goes too low, alarms should sound and fans cycle off.

5. At locations that have sustained periods of low ambient temperatures, the design should include the ability to run “defrost” cycles. Defrost cycles include periods of pump operation with fan motors de-energized. The length and frequency of defrost cycles should be determined by frequent tower inspections to ascertain the degree of ice build up.

6. When even more severe cold weather is expected, the design should incorporate the ability for reverse fan operation at half speed during defrost cycles. When very low ambient conditions cause difficult icing conditions, reverse fan operation will usually carry the entire heat load. Note that most variable frequency drives can be programmed for reverse fan rotation.

   This option should be reserved only for extreme icing conditions.

Troubleshooting Guide for Cooling Towers Operating in Low Ambient Conditions

1. First, determine where the ice is beginning to form (ie. On the fill, inlet louvers, water distribution system etc.).

2. Next, determine out what operational condition has arisen. Examples are:
   - Ice/water on the building roof
   - Loss of cooling capacity
   - Mechanical vibration

3. Determine the operating conditions of the tower:
   - What are the flow rates and operating temperatures?
   - Where are the sensing devices located?
   - What is the operating sequence for fan and pump control?
   - What type of application is the tower cooling?
   - Is the installation suing a pump suction or remote sump?

4. Determine the layout conditions. Does the installation meet EVAPCO guidelines? What is the speed and direction of the prevailing winds?

5. Determine the condition of the cooling tower.
   - Has the tower been kept clean?
   - Are the nozzles free and clear?
   - Were there any leaks prior to the winter season?

6. Lastly, ascertain what has been tried and how that has worked.

Following an evaluation, you may offer several options to help control ice formation and aid in tower operation. These are listed below in order of increasing severity of ice formation. Ice formation should also be linked with the ambient conditions, therefore, the colder the weather, the greater the requirement for improved system control.

1. Concentrate the load in a few cells as possible to increase water loading to aid in ice management.

2. Install extended drop angles in the basin area to reduce the amount of water splashing onto the inlet louvers.

3. Utilize off-cycling in the fan operation to allow the pumps to circulate water over the tower to control ice formation.

4. Incorporate reverse fan operation on low speed to aid in removal of ice from inlet louvers. This requires two speed motors and starters or a variable frequency drive with reversing capability.

Please note that the majority of installations do not require reverse fan operation. This should be reserved only for units with extreme icing conditions.