ENGINEERING BULLETIN

No. EB23D

Product: Cooling Towers – Free Cooling Operation **Date: April 16, 2010**

Table of Contents

I. Introduction:

Cooling towers are used to dissipate heat from air conditioning or industrial process systems. Many of the air conditioning systems currently in use only operate during the summer cooling season, but there are numerous air conditioning and process systems that require cooling year-round. In some cases, the entire cooling system is required to operate during the winter. The cooling tower is required to provide the same 85° F or colder water to the system as it does in the summer, but it does so at lower ambient temperatures. However, there are some applications designed to use the cooling tower for “free cooling”. Free cooling is when chilled water is cooled by cooling tower water through the use of heat exchangers without the use of refrigerant compressors. Free cooling can be accomplished when ambient conditions allow the cooling tower to produce “chilled water” for the system.

When the tower is providing “chilled water” to the system, there are periods of time when it must operate in subfreezing conditions. During these periods, when the tower is subjected to very cold ambient conditions, there is greater potential to produce ice in the cooling tower or elsewhere in the system. If an inappropriate cooling tower design is chosen, or if the unit is not operated or winterized properly, excessive amounts of ice can form in the unit resulting in decreased capacity, operational difficulties, and potential damage to the tower.

Cooling tower performance in free cooling applications is dependent upon both the system and cooling tower design. The control sequences applied to the cooling system must consider *management of both the air and water side* of the cooling tower. It is essential that the proper control sequences be applied during free cooling to ensure adequate operation of the cooling tower during low ambient conditions.

When a requirement for free cooling is specified for a project utilizing cooling towers, certain considerations must be made from the very beginning of the project design. First, special care must be taken when laying out the cooling towers to prevent recirculation due to poor tower location and prevailing winds. If a strong prevailing wind is present, adding “wind walls” to an induced draft tower should be considered. Second, the cooling tower should be equipped with basic options such as basin heaters, electric water level control, and vibration switches to prevent operational issues due to basin freezing if a remote sump is not possible. Lastly, capacity control must also be carefully considered, especially if the winter cooling load is significantly less than the summer load. Shutting down individual cells of a multiple cell cooling tower or employing a low-flow header on a singe cell should be utilized. A minimum leaving water temperature of 45°F must be maintained at all times.

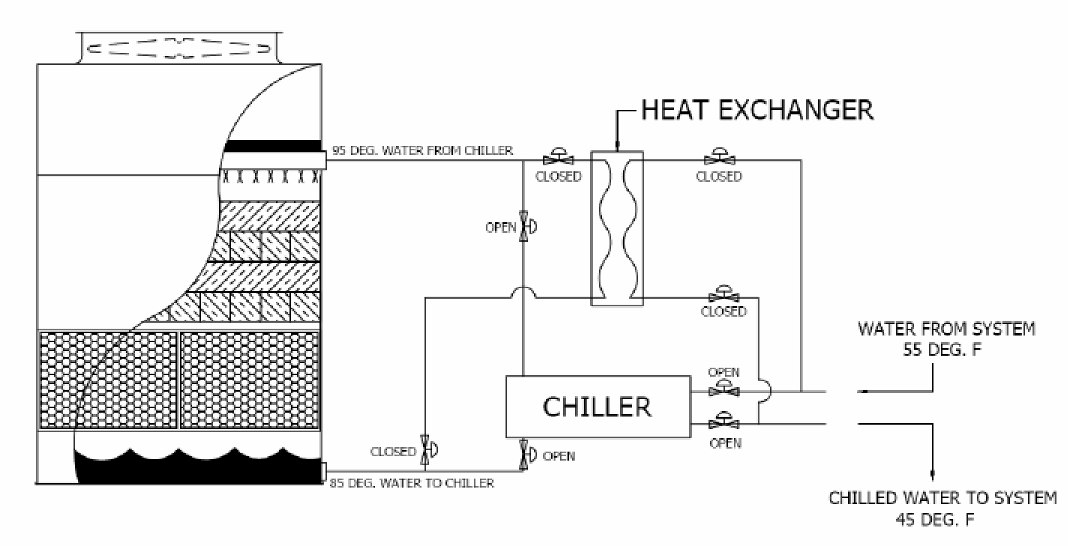
Evapco’s counterflow cooling towers are well suited for free cooling operation. In a counterflow cooling tower, the fill is completely enclosed and protected from outside elements, such as wind, that can cause freezing of the fill pack in low ambient conditions. Additionally, the fill pack is supported from below to prevent sagging in the event freezing should occur due to a system imbalance. The fans, fan motors, and drive systems of Evapco counterflow cooling towers are also designed to be safely run in reverse at up to 50% normal fan speed. However, there are several items to consider when operating a counterflow cooling tower in a free cooling mode. This engineering bulletin will examine the following items in detail: cooling tower design considerations, capacity control and ice management methods for both forced and induced draft units, and proper maintenance procedures to ensure successful operation of the cooling tower during free cooling. The appendix to this bulletin includes a quick-reference summary of the various capacity control sequences as well as system design and troubleshooting guidelines.

Background:

Normal Operation:

An examination of free cooling should begin with a review of the normal operation of the cooling tower during the summer cooling season. The schematic shown in Figure 1 details the operation of the cooling system during typical summer conditions. The chiller is operational and cooling the system chilled water. In a traditional system, the chilled water returns from the conditioned space at 55° F where it has absorbed the heat from the conditioned space. It is then cooled in the evaporator shell of the chiller before being sent back to the conditioned space at 45° F. For these conditions, the chiller and the cooling tower are operating while the heat exchanger shown is isolated from the system and is not included in the system operation.

Simultaneously, the cooling tower is absorbing the building load plus the heat of compression. The cooling tower then transfers this heat load to the atmosphere. In a typical air conditioning system, the water leaves the condenser shell of the chiller and enters the cooling tower at 95° F. The hot water is then cooled to 85° F and then sent back to the condenser shell of the chiller to continue the heat transfer process.

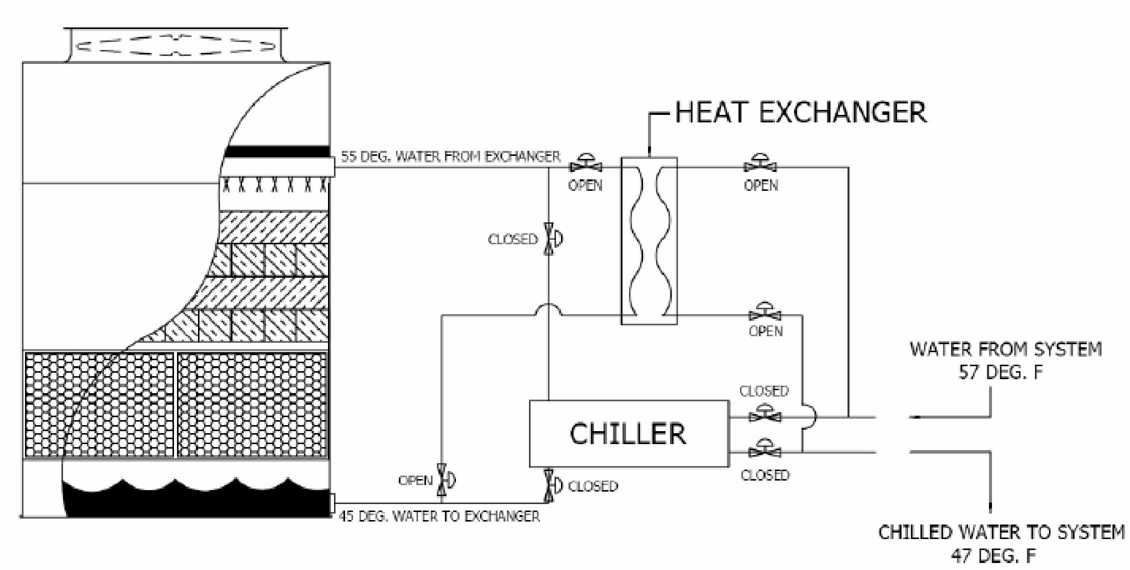


Tower = 85°F Leaving Water Temperature
Chiller = 45°F Leaving Water Temperature

Figure 1: Cooling System Schematic: Normal Summertime Operation

Free Cooling Operation:

During free cooling, the chiller is not operating. The cooling tower absorbs the building heat load and rejects it to the atmosphere. During the free cooling operation, the cooling tower does not need to remove the heat of compression since the chiller is not operating. The chiller is isolated, and the water from the cooling tower and the conditioned space is bypassed to the heat exchanger. Low ambient conditions allow the cooling tower to provide “chilled water” temperatures as low as 45° F to the primary side of the heat exchanger where it absorbs the building heat load before being returned to the cooling tower. A 2° F approach can be achieved in the heat exchanger where 47° F water on the secondary side provides cooling to the building. Since the cooling loads and the requirement to remove the humidity from the building are reduced in the winter, the “free cooling” chilled water temperatures can be higher than those during summer operation. The temperatures shown in the schematic are typical but are dependent on system loads, winter design conditions, and desired building temperatures. The design engineer is responsible for defining the system parameters which will allow you to select an appropriate cooling tower for the free cooling operation.



Tower = 45°F Leaving Water Temperature
Heat Exchanger = 47°F Leaving Water Temperature

Figure 2: Cooling System Schematic: Free Cooling Operation (Indirect System)

II. Free Cooling: System Design Considerations

When considering a free cooling application, it is important to properly plan the design of the cooling tower system. The following items should be considered during the design phase of a project:

- Cooling Tower Selection
- Unit Layout
- Cooling Tower Piping
- Cooling Tower Accessories
- Transition from Free Cooling to Mechanical Cooling

Cooling Tower Selection:
The first item to consider when designing a cooling tower system is the primary design condition – summer conditions or winter (free cooling) conditions. This design condition will drive the unit selection. If the winter condition is driving the unit selection, a larger unit will be required than would be normally selected for summer only operation. This occurs because it is more difficult for the cooling tower to reject heat at low ambient operating conditions. Further, although a single cell unit may meet the summer and winter design conditions, a multiple cell unit may be a better selection for winter operation. Since the water flow rate for winter operation may be less than the summer flow rate, it can be concentrated in fewer cells, which allows the flow rate per cell to remain high, thus reducing the potential for ice formation inside the tower. Multiple cell units also provide backup capacity if an operating cell requires defrosting or were to fail.

Unit Layout:
Careful consideration must be given to the proper location and layout of the cooling tower(s) on every project. Adequate unobstructed air flow must be provided for both the intake and discharge of the unit. It is **imperative** for cooling towers used for free cooling that the equipment **layout minimizes the potential for recirculation**. During summer operation, recirculation can dramatically reduce the cooling tower capacity, however during winter operation it can result in condensate freezing on the inlet louvers, fans, fan shafts, and fan screens. The buildup of ice in these areas can adversely affect air flow to the unit or, in more severe cases, lead to failure of these components. EVAPCO strongly encourages the use of a vibration switch on units that are to be used for winter operation.

See Figure 3 for correct and incorrect installations for forced and induced draft units.

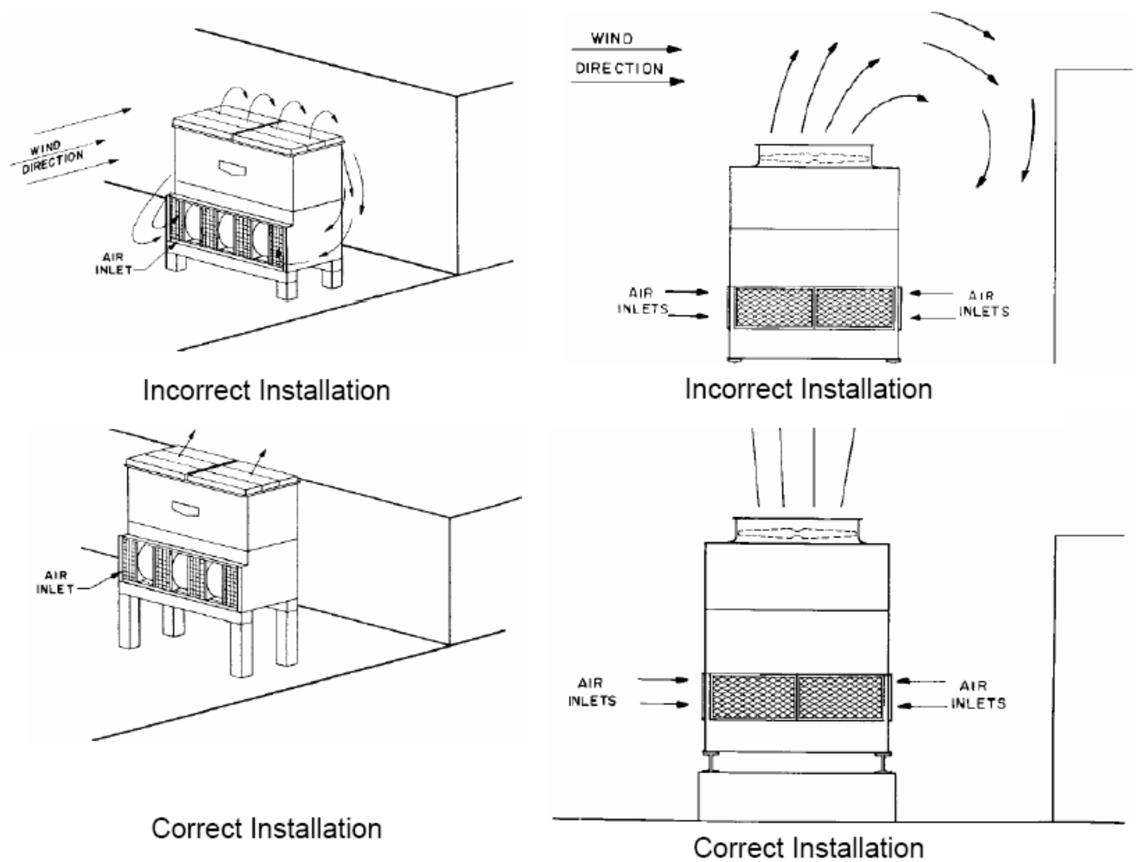


Figure 3: Correct and Incorrect Layouts for Forced and Induced Draft Units.

Cooling tower performance can be affected by prevailing winds. High winds can create icing conditions on the inlet louvers and fan screens, adversely affecting air flow to the tower. EVAPCO **can install *"wind walls"* in its induced draft cooling towers to help alleviate the problems associated with installations that experience high winds** (see Figure 4).

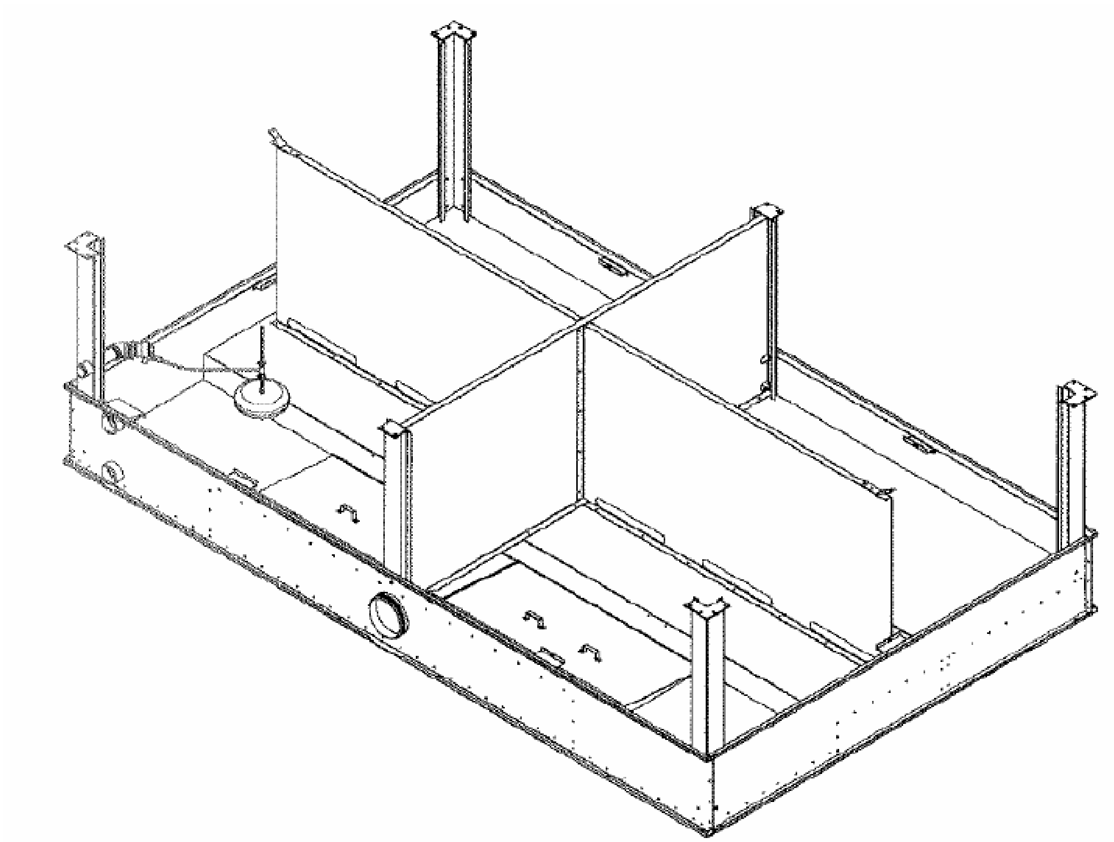


Figure 4: Wind wall Installation

In addition, the prevailing winds in poor unit layouts can cause a downward airflow of the moisture laden discharge air, which can condense on the unit surfaces and quickly freeze. This phenomenon promotes ice formation on the inlet louvers of induced draft units and on the fans of forced draft units.

For more information on cooling tower layout, please refer to EVAPCO Equipment Layout Bulletin 311.

Cooling Tower Piping:

When designing a cooling tower system for free cooling applications, several piping details should be considered to ensure proper winter operation of the unit. A cooling tower bypass needs to be incorporated into the system design to allow water to "bypass" the tower's water distribution system as a means of capacity control during low load conditions. There are several ways to design the system piping to accommodate the cooling tower bypass.

EVAPCO recommends that the cooling tower bypass be installed in the condenser water piping system. A bypass installed in this manner will require a section of pipe between the condenser water supply and return leading to and from the cooling tower.

Bypassing the cooling tower water directly into the cold water basin is another method of a cooling tower bypass. Evapco can provide a factory installed bypass connection in the cold water basin of the tower. Refer to Engineering Bulletin 33 for further information on cooling tower bypass connections. In either method of bypass (in the system piping or tower sump), it is good practice to install the bypass valve below the cold water basin level to assure good head pressure on the valve.

Regardless of what type of bypass arrangement is used, Evapco recommends that only a **FULL FLOW BYPASS** be used during free cooling operation. This means that the total flow rate to the tower must either be sent to the water distribution system or bypassed. ALTHOUGH IT MAY BE ACCEPTABLE TO USE A PARTIAL BYPASS DURING THE SUMMER, **NEVER USE A PARTIAL COOLING TOWER BYPASS DURING FREE COOLING OPERATION!** Reduced flow over the tower can result in uneven water flow over the heat transfer media (fill) which can cause scaling during summer operation and ice formation during winter operation.

Freeze Protection:
Another important consideration during free cooling system design is to ensure that the necessary piping and accessories are heat traced and insulated. All water inside the cooling tower drains (by gravity) to the cold water basin – no additional provisions are required within the cooling tower. However, all external piping that does not drain (makeup water lines, equalizers, and riser piping) must be heat traced and insulated to ensure that they do not freeze. System piping accessories (makeup water and control valves, water circulation pumps, and water level control packages) also require heat tracing and insulation. If any of these items are not heat traced and insulated, the ensuing ice formation in these components may result in failure causing a shutdown of the cooling tower(s).

Cooling Tower Accessories:
The major concern when operating a cooling tower during the winter for free cooling is freeze protection. If a cooling tower does not have the appropriate accessories, excessive amounts of ice may form inside or on the unit which could lead to a significant reduction in thermal capacity or a catastrophic equipment failure. However, the appropriate accessories to prevent or minimize ice formation during free cooling operation are relatively simple and inexpensive. These accessories include multi-speed or inverter duty motor(s), wind walls,

extended drip angles, cold water basin heaters, remote sump connections, electronic water level control and vibration cutout switches. Each of these accessories ensures that the cooling tower will function properly during continuous low-ambient temperature operation.

Multi-Speed Motors:
When cooling towers are utilized in a free cooling application, it is important that they are supplied with motors that can be operated at reduced speed and in reverse up to 50% speed. This is to allow the leaving water temperature to remain as low as possible and to allow for a defrosting cycle.

Extended Drip Angles:
Drip angles are used in all AT-style cooling towers to direct the water away from the air inlet louvers. Extended drip angles are most effective in extremely cold environments when the cooling towers are utilized for free cooling. Extensions of up to 18” are available for installation either as a factory installed option or in the field as a retrofit. Years of field experience has shown that drip angle extensions of up to 6” are very effective for most climates and have insignificant effects on summer cooling tower thermal performance. Extensions over 6” and up to 18” are designed to be removable. This allows for excellent winter operation and excellent summertime performance as well. Extended drip angles are particularly helpful during periods of reduced fan speed operation, when they can be utilized to further direct the system water into the center of the basin and away from the inlet louver surfaces. Contact EVAPCO’s Marketing Department for performance implications and pricing.

Wind Walls:
Wind walls can be utilized on units in order to reduce “blow-through” a cooling tower basin when a tower is sited in a location with strong prevailing winds. This reduces the potential for ice build-up on the wind-exit side of the basin, as well as the potential for ice build-up on surfaces inside the cooling tower basin.

Cold Water Basin Heaters:
Basin heaters can be furnished with the cooling tower to prevent the water from freezing in the basin when the tower is idle during low ambient temperatures. The basin heaters are designed to maintain a minimum basin water temperature of 40°F at a 0° F ambient temperature. The basin heaters are only energized when the condenser water pumps are off and no water is flowing over the tower. As long as there is a heat load and water is flowing through the tower, the heaters do not need to operate. The standard factory-supplied basin package uses electric immersion heaters. However, other types of heaters such as hot water and steam coils or steam injectors can be furnished by EVAPCO. In addition, if ambient conditions below 0°F are anticipated, higher capacity heaters can be furnished. Contact EVAPCO’s Marketing Department for heater sizing.

Electric Water Level Control:
For cooling towers that are to be used for free cooling applications, EVAPCO recommends the use of the optional electronic water level control package. This package replaces the standard mechanical float and valve assembly and consists of a three probe water level sensor mounted in a PVC standpipe assembly which electronically controls a solenoid type makeup valve with “y” strainer. The electronic water level control eliminates the freezing problems that can occur with the standard mechanical float assembly. In addition, it provides very accurate control of the basin water level and does not require field adjustment even under varying load conditions. Note that the standpipe assembly, makeup water piping and solenoid valve must be field heat traced and insulated to prevent them from freezing.

Remote Sump:
A remote sump located in an indoor heated space is an excellent way to prevent freezing in the cold water basin of the cooling tower during idle or no load conditions. EVAPCO can provide connections in the cold water basin to accommodate for remote sump installations. Refer to Engineering Bulletin 30 for proper sizing and quantity of remote sump connections. Please note that although units with remote sump operation do not require pan heaters, electronic water level control, makeup water valves or bypass connection installed in the cold water basin, the potential for freezing problems during free cooling operation still exists.

Vibration Cutout Switches:
Another useful accessory for units operating during the winter is a vibration switch. During severe winter conditions, ice can form on the fans of cooling towers causing excessive vibration. Should this condition occur, the vibration switch shuts off the fan avoiding potential damage to or failure of the drive system.

III. Capacity Control Methods:

Induced draft and forced draft cooling towers require separate guidelines for capacity control during free cooling applications, which are detailed on the following pages.

The sequence of control for a cooling tower operating during low ambient conditions is much the same as a cooling tower operating under summer conditions, provided the ambient temperature is above freezing. When the weather becomes very cold, additional precautions must be taken to avoid the potential for damaging ice formation.

It is very important to maintain close control of the cooling tower during winter operation. EVAPCO recommends that a **MINIMUM leaving water temperature of 45°F** must be maintained during free cooling operation. However, laboratory testing and field experience has shown that 42°F should serve as the ABSOLUTE MINIMUM leaving water temperature. Obviously, the higher the leaving water temperature from the tower, the lower the potential for ice formation. This assumes that the proper water flow over the cooling tower is maintained and the fan operating procedures mentioned in the bulletin are followed.

The following pages provide a summary of the capacity control sequences for both induced and forced draft units. A sequence of operation for towers utilizing single speed, two-speed, and variable speed motor controls are shown. Also included are the capacity control considerations for multiple cell cooling towers. In the Appendix of this bulletin, the recommended capacity control sequences are shown in further detail for cooling towers operating during free cooling conditions.

Capacity Control (Induced Draft):

Capacity control of induced draft cooling towers operating during free cooling applications can be achieved using a variety of methods. The most common methods of capacity control are:

Cycling Single Speed Fan Motors
Using Two Speed Fan Motors
Using Variable Frequency Drives (VFD's)

The simplest method of capacity control of a cooling tower during free cooling operation is cycling the fan motor on and off in response to the leaving water temperature of the tower. However, this method of control results in larger temperature differentials and longer periods of time with the fans off. During extremely low ambient conditions, the moist air may condense and freeze on the fan drive system. Therefore, fans must be cycled during extremely low ambient conditions to avoid long periods of idle fan operation whether the water is flowing over the fill, or in bypass. Please note that excessive fan cycling may cause fan motor damage: the number of fan motor starts and stops should be limited to six per hour. If the building loads are small, the tower will see extended periods with the fans off, causing a greater potential for icing to occur on the intake louvers of the unit. As a result, cycling single-speed fan motors is the least recommended method of capacity control.

Another method of capacity control is to use two-speed fan motors, which include an additional step of capacity control. This step reduces the water temperature differential, and therefore the amount of time that the fans are off. In addition, two speed motors provide a significant savings in energy costs, since the tower has the potential to operate on low speed for the majority of the free cooling season.

The most accurate method of capacity control for an induced draft tower is to use variable frequency drives. This allows much closer control of the leaving water temperature by allowing the fan(s) to run at the appropriate speed to closely match the building load. However, the application of a VFD with an induced draft cooling tower could contribute to the formation of the ice during sub-freezing conditions. As the building load decreases, the variable frequency control system may operate for long periods of time at fan speeds below 50 percent. Operating at low leaving water temperatures and low air velocity through the unit can cause ice to form at various locations in the unit. Therefore, **it is recommended that the MINIMUM speed of the variable frequency drive be set at 50 percent of full speed to minimize the potential for ice to form in the unit during low ambient cooling tower operation**. See the Ice Management section for additional information.

Please note the following concerning critical fan speeds: All current lines of EVAPCO induced draft towers utilize fans that do NOT have critical speeds. However if an older EVAPCO induced draft cooling tower is to be retrofitted for free cooling duty, there may be critical fan speeds that need to be avoided. Please refer to Engineering Bulletin # 39 for information on applying variable frequency drives to cooling towers.

Capacity Control (Forced Draft):

Capacity control of forced draft cooling towers operating during free cooling applications can be achieved by several different methods. Similar to the induced draft units, the most common methods of capacity control are cycling single speed fan motors, using two speed fan motors or pony motors, or utilizing variable frequency drives to control the cooling tower fan(s). Although capacity control methods for forced draft units are similar to those used for induced draft units, there are several major differences detailed below.

The simplest method of capacity control for a forced draft units is to cycle the fan(s) on or off. However, this method of control results in larger temperature differentials and periods of time with the fans off. When the fans are cycled off, the water falling through the unit can induce air flow through the fan section. During extremely low ambient conditions, this moist air may condense and freeze on the cold components of the fan drive system. If conditions change and cooling is needed, the excessive amounts of ice that may have formed on the drive system can destroy fans and fan shafts that are suddenly required to operate. Therefore, fans MUST be cycled during low ambient operation to avoid long periods of idle fan operation. Please note that excessive cycling can damage the fan motors. Limit the number of starts to six per hour.

Two speed or pony motors offer a better method of control than single speed motors. The two speed motor control will allow an additional step of capacity control, reduce water temperature differentials and the amount of time that fans are off, and provide savings in energy costs. This method of capacity control has proven effective for applications where load variations are excessive and winter conditions are moderate.

Variable frequency drives provide the most flexible method of capacity control for forced draft cooling towers. The variable frequency drive 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 (25% of full speed) which ensures a positive pressure inside the unit. This positive pressure in the unit prevents moist air from migrating towards the cold fan drive components reducing the potential for condensation to form and then freeze on them. The variable speed drive method of control should be implemented for applications that experience fluctuating loads and severe winter temperatures.

Capacity Control (Multiple Cell Units):

Multiple-cell induced and forced draft cooling towers require different control sequences than single cell cooling towers. It is important that the fans and water flow over each cell be controlled properly on multiple cell cooling towers.

Proper fan control is essential to avoid the potential for building ice in one of the cells of a multiple-cell cooling tower. All fans in operating cells MUST be controlled simultaneously to avoid freezing conditions in any one cell. The correct method for fan control of a multiple-cell cooling tower during free cooling operation is shown in figure 6. Instead of cycling one fan on and one fan off; both fans should be operated together at low speed in order to reach a 45 degree leaving water temperature. This method of operation has the same 65 degree water entering both cells; however with both fans operating at low speed, this allows 45 degree water to enter the basin from each cell. The final leaving water temperature of the cooling tower is 45 degrees, and the potential for freezing in any one cell is eliminated.

The **INCORRECT** method of multiple cell fan control is shown below in figure 5. In this example, 65 degree system water is pumped through each cell's water distribution system. However, the fan in Cell 1 is off and the fan in Cell 2 is on. Since the fan is off in Cell 1 water entering the basin is 55 degrees, and the fan of Cell 2 is on water entering the basin is 35 degrees, the resulting net water temperature between the basins is 45 degrees. This meets the required minimum temperature of 45 degrees; however the Cell 2 temperature is too low which may result in localized freezing.

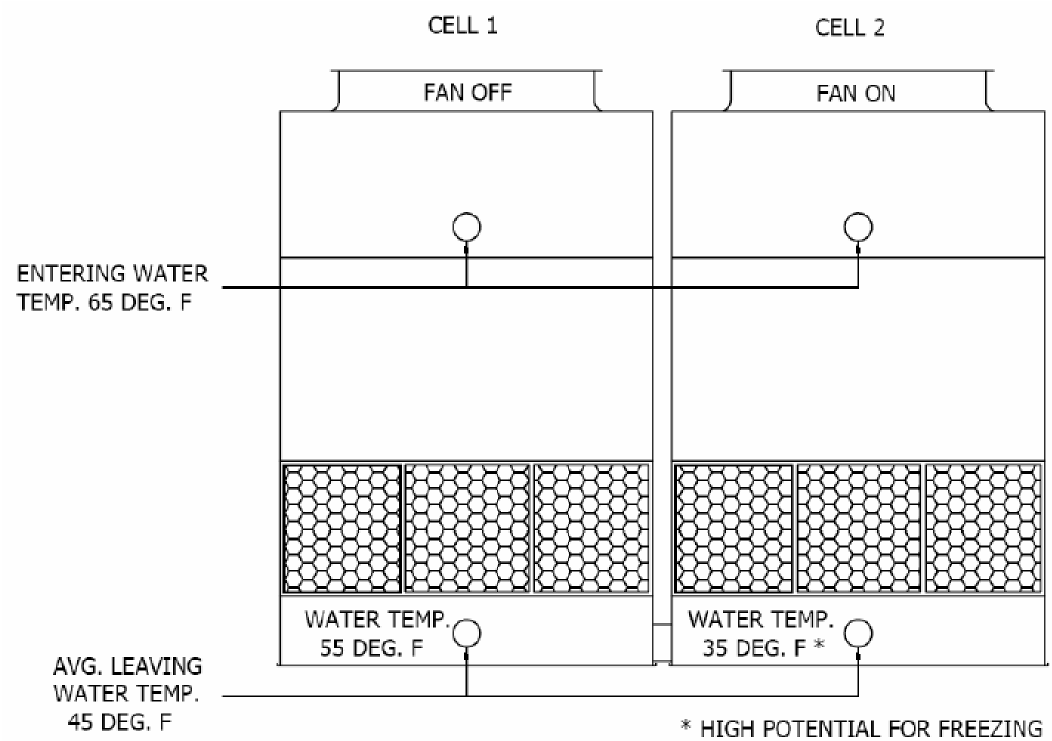


Figure 5: Incorrect Method of Multiple Cell Fan Operation

Along with providing the proper fan control, it is also strongly recommended that the leaving water temperature be monitored in all cells. The basin temperature sensors can be placed in either the suction piping or the cold water basin. This can help determine possible icing conditions in each cell. However, if two cells operating together have too much capacity causing excessive fan cycling, then directing all of the load to one cell and shutting down the other cell completely should be considered.

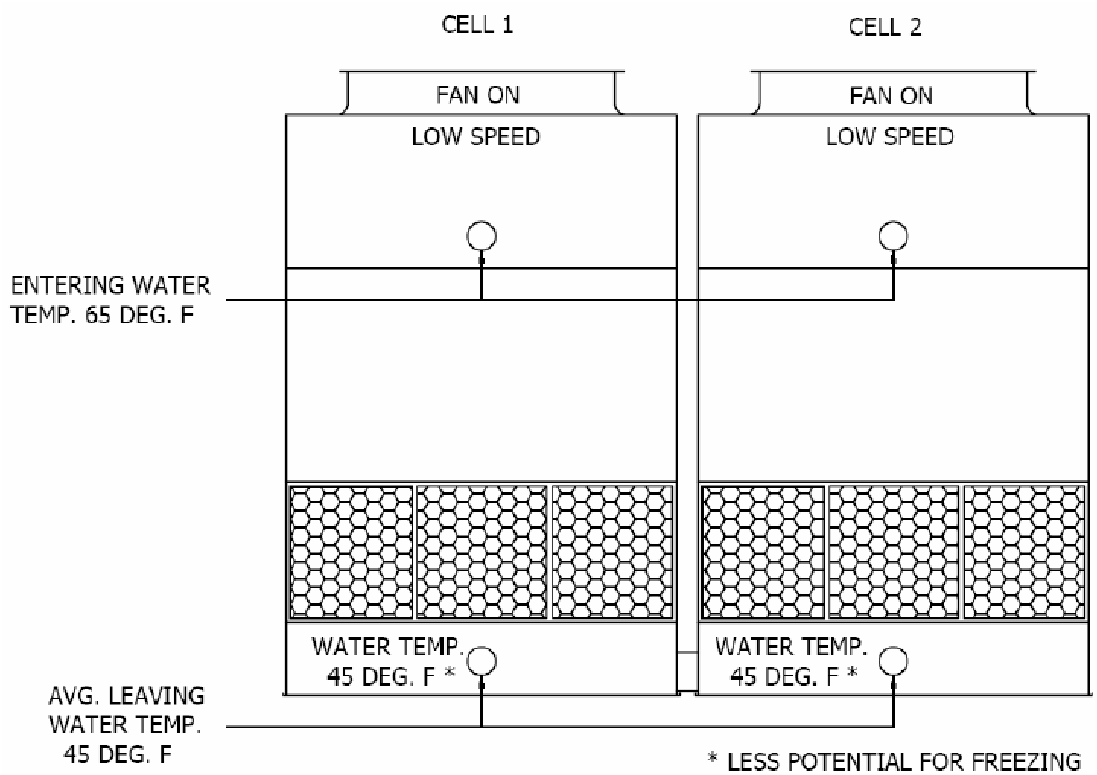


Figure 6: Correct Method of Multiple Cell Fan Operation

Typically, the winter cooling loads are much less than what is seen during the summer cooling season. Therefore, the water flowrate through the tower may be reduced, which can create the potential for ice buildup on or inside the unit. **EVAPCO recommends that the water flowrate be directed to as few cells as possible, since the cooling tower performs better with the system flowrate as near the design flow per cell as possible. This ensures that the water distribution system maintains a proper spray pattern over the fill and avoids a low flow condition that can lead to ice formation inside the cooling tower.**

In some cases, design winter flow rates are reduced beyond the lower limits of the spray nozzle performance range. In this case, a special water distribution system can be incorporated to accommodate the winter design flowrate. This design may utilize an additional water distribution system with spray nozzles that are capable of performing under very low flow conditions, or may be done by simply using an EvapJet® nozzle with a smaller orifice. Typically, the additional water distribution system is limited to one cell of the induced draft cooling tower. Please contact the Marketing Department for sizing, selection, and feasibility of using a low-flow header for free cooling applications. Currently, this approach would only be taken for a retrofit application.

All AT style cooling towers currently utilize the *Variflow* header system. This system uses the EvapJet® nozzle to effectively manage system water flow over the cooling tower fill between 100% and 50% of the design flowrate. If the winter or free-cooling design flowrate is less than 50% of the summer design, please contact the EVAPCO Marketing department for an alternate header design selection.

IV. ICE MANAGEMENT:

When operating a cooling tower in subfreezing ambient conditions during free cooling mode, the formation of ice is possible. The key to successful operation during cold winter conditions is to control or manage the amount of ice that builds up in and on the unit. If excessive ice build-up occurs, it can lead to severe operational difficulties as well as damage to the cooling tower. The following pages provide ice management methods for both induced draft and forced draft cooling towers. Following these guidelines will minimize the amount of ice that forms in and on the cooling tower, which will lead to better operation during the free cooling season.

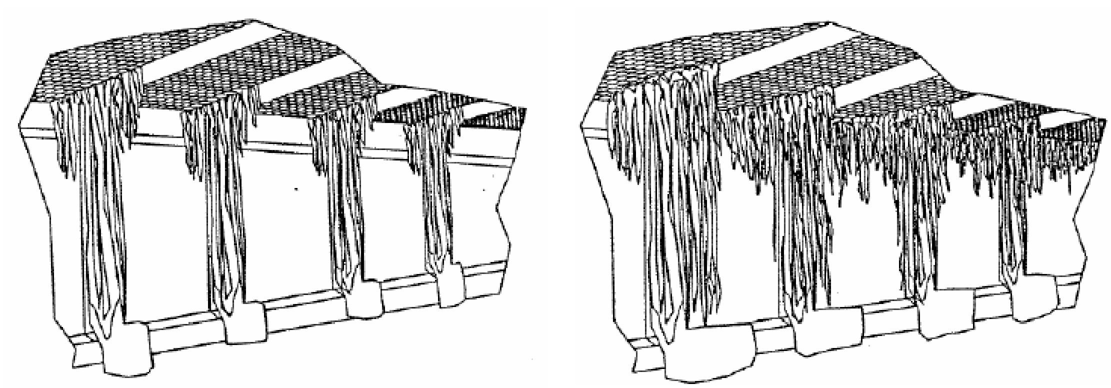
INDUCED DRAFT UNITS:

When operating an induced draft cooling tower during the winter for free cooling, the control sequence must have a method to manage the formation of ice in and on the unit. The simplest method of managing the amount of ice buildup is by cycling the fan motor(s) off. During these periods of idle fan operation, the warm water that is absorbing the building load flows over the cooling tower to help melt any ice that has formed in the fill, basin or louver area. In more severe climates, the incorporation of a defrost cycle may be used to manage the ice formation in and on the unit. During the defrost cycle, the cooling tower fan(s) are reversed at ***no more than half speed*** while the system pump flows water through the cooling tower's water distribution system. Operating the unit in "reverse" will melt any ice that has formed in the unit or on the intake louvers. Please take note that the fans may need to be cycled off prior to a defrost cycle to assure the can comes to a complete stop and allow the water temperature to rise. **NOTE: the defrost cycle requires the use of reversible variable frequency drives or two speed motors with reverse cycle starters.** All multi-speed or VFD duty motors supplied by EVAPCO, whether for standard belt drive or optional gear drive induced draft units, are capable of reverse operation.

The defrost cycle should be incorporated into the normal control scheme of the cooling tower system. The control system should allow for either a manual or an automatic method to control the frequency and duration required to completely melt the ice from the cooling tower. The frequency and duration of this defrost cycle is dependent on the control methods, the actual load, and ambient winter conditions. Some applications will build ice quicker than others, thus requiring longer and more frequent defrost periods. Therefore, frequent inspection of the tower during the free cooling season will help "fine tune" the frequency and duration of the defrost cycle.

CAUTION: Running a defrost cycle during EXTREME ambient conditions may exacerbate a freezing problem. Consider the amount of heat entering the cooling tower and compare to the large volumes of very cold ambient air. Frequent inspections are recommended if a defrost cycle is planned during extremely low ambient temperatures.

Figure 7 shows acceptable and unacceptable levels of ice formation for an induced draft counterflow cooling tower. This figure illustrates that excess ice formation should be avoided between defrost cycles, since extreme amounts of ice buildup can damage the unit(s) or become a hazard to the building or its occupants if it falls.



Acceptable Counterflow Ice   Unacceptable Counterflow Ice

Figure 7: Acceptable and Unacceptable Counterflow Ice Formation

FORCED DRAFT UNITS:

Defrost cycles are NOT recommended for forced draft cooling towers, since allowing the leaving water temperature set point to rise causes the fans to be off for very long periods of time, which for forced draft towers increases the potential for freezing of the fan drive components. In lieu of a defrost cycle, forced draft units should be operated at low speed (with a 2-speed motor) or minimum speed (no lower than 25% with a variable frequency drives) in order to maintain positive pressure inside the unit which helps prevent ice formation on the fan drive components.

V. Unit Maintenance:

The best way to maintain cooling tower performance during the free cooling season is to ensure that the unit is in proper working condition. Normal routine maintenance should be performed on a more frequent basis than during summertime operation and any major repairs should be done before the winter cooling season arrives. The fan shaft and motor bearings (if applicable) should be lubricated properly to prevent moisture infiltration and freezing in the bearings. The belt tension should be checked and adjusted if not within the desired limits. The EVAPCO Maintenance Checklist (Appendix A) should be reviewed for a complete list of all maintenance items and their required frequency.

In addition to properly maintaining the cooling tower, frequent inspections during the free cooling season are strongly recommended. At a minimum, daily inspections should be made, although more frequent inspections are encouraged. Mornings are the most important time to conduct cooling tower inspections. During these daily inspections, it is advisable to do the following:

- check the strainers for cleanliness,
- verify that there is a proper spray pattern from the water distribution system,
- ensure that the float valve assembly is in proper working order,
- check the basin water level,
- check for any indications where ice buildup could lead to potential fan drive component failures.

On a regular basis, inspect the fan and motor bearings (if applicable) for proper lubrication and analyze the water quality to verify that it is within the recommended guidelines.

Other important items to check on a less frequent basis are: the basin heaters (if supplied); electronic water level control (if supplied); and heat tracing (if supplied) to make sure that they are operative.

Finally, periodically check for and repair piping or cold water basin leaks to ensure that a hazardous icing condition near the tower does not occur. Proper maintenance and frequent tower inspections are a relatively inexpensive form of cooling tower “insurance” and it can alleviate the many problems that cooling towers experience during the free cooling season.

Conclusions:

Using a cooling tower for free cooling operation is an excellent method of reducing energy consumption and costs. However, proper system planning is required during the design stage. Additionally, proper unit selection, layout, piping and control sequences must be implemented. Methods for ice management must also be incorporated into the cooling tower control sequence. Finally, once the system is in place and operating, it needs to be properly maintained so that it can provide trouble free performance during the free cooling season.

APPENDIX A

MAINTENANCE CHECKLIST

PROCEDURE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1. Clean pan strainer – monthly or as needed												
2. Clean and flush pan** – quarterly or as needed												
3. Check bleed-off valve to make sure it is operative – monthly												
4. Check operating level in pan and adjust float valve if necessary – monthly												
5. Check water distribution system and spray pattern – monthly												
6. Check drift eliminators – quarterly												
7. Check the fan blades for cracks, missing balancing weights, and vibrations - quarterly												
8. Lubricate fan shaft bearings* - every 1000 hours of operation or every three months												
9. Lubricate fan motor bearings – see mfg's instructions. Typically for non-sealed bearings, every 2-3 years												
10. Check belt tension and adjust – monthly												
11. Sliding motor base – Inspect and grease – annually or as needed												
12. Check fan screens, inlet louvers and fans. Remove any dirt or debris - monthly												
13. Inspect and clean protective finish – annually -Galvanized: scrape and coat with ZRC -Stainless: clean and polish with a stainless steel cleaner.												
14. Check water quality for biological contamination. Clean unit as needed and contact a water treatment company for recommended water treatment program** – regularly												

OPTIONAL ACCESSORIES:

1. Gear Reducer – Check oil level with unit stopped – 24 hours after start-up & monthly												
2. Gear Reducer/Piping – Do visual inspection for oil leaks, auditory inspection for unusual noises and vibrations – monthly												
3. Gear Reducer - Replace oil – semi-annually												
4. Oil Pump – Do visual inspection for leaks and proper wiring – monthly												
5. Gear Reducer/Coupling – Check alignment of the system – 24 hours after start-up & monthly												

*See maintenance manual for start-up instructions and lubrication recommendations
** Cooling Towers must be cleaned on a regular basis to prevent the growth of bacteria including Legionella Pneumophila

MAINTENANCE CHECKLIST

PROCEDURE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
6. Coupling/Shaft – Inspect flex elements and hardware for tightness, proper torque & crack/ deterioration – monthly												
7. Heater Controller – Inspect controller and clean probe ends – quarterly												
8. Heater – Inspect junction box for loose wiring and moisture – one month after start-up and semi-annually												
9. Heater – Inspect elements for scale build-up – quarterly												
10. Electronic Water Level Controller – Inspect junction box for loose wiring and moisture – semi-annually												
11. Electronic Water Level Controller – Clean probe ends of scale build-up – quarterly												
12. Electronic Water Level Controller –Clean inside the standpipe – annually												
13. Solenoid Make-up Valve – Inspect and clean valve of debris – as needed												
14. Vibration Switch (mechanical) – Inspect enclosure for loose wiring and moisture – one month after start-up and monthly												
15. Vibration Switch – Adjust the sensitivity – during start-up and annually												
16. Sump Sweeper Piping – Inspect and clean piping of debris – semi-annually												
17. Water Level Indicator – Inspect and clean – annually												
DURING IDLE PERIODS:												
1. Few Weeks: Run gear reducer for 5 minutes – weekly												
2. Several Weeks: Completely fill gear reducer with oil. Drain to normal level prior to running.												
3. One Month or longer: Rotate motor shaft/fan 10 turns – bi-weekly												
4. One Month or longer: Megger test motor windings – semi-annually												

APPENDIX B: Induced Draft Towers: Two Speed Fan Motor Control Sequences

System Off / No Load
System pumps and fans off. Basin heaters cycle, as required, to maintain minimum basin water temperature (40ºF).

System Temperature Rises
System pumps turn on. Interlock in pump starter turns basin heaters off. Tower supply valve is positioned to allow full water flow to bypass the tower's water distribution system.

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

If the system temperature continues to rise, the tower fan motor(s) is turned to low speed. In multiple cell units, the fans in each operating cell are turned to low speed. ALL OPERATING CELLS IN MULTIPLE CELL TOWERS MUST BE CONTROLLED TOGETHER TO PREVENT ICING IN THE BASIN.

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

System Temperature Stabilizes
Control the tower leaving water temperature by cycling fans between high and low speeds. Allow for a 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 allowing the system water temperature to rise and melt the ice that may have formed in the unit. Allow for a time delay when reversing fans. Inspect the tower regularly during sub-freezing temperatures to determine the frequency and length of the defrost cycle.

System Temperature Drops
If the system temperature drops to the minimum control point, turn the fans off. If the system temperature drops to below the minimum control point, the tower supply bypass valve opens to allow full flow to bypass the tower's water distribution system.

System Off / No Load
System pump and tower fans turn off. Starter interlock energizes the basin heaters.

NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42ºF

APPENDIX C: Induced Draft: Variable Speed Fan Motor Control Sequence

System Off/ No Load

System pumps and fans off. Basin heaters cycle, as required, to maintain minimum basin water temperature (40°F).

System Temperature Rises

System pumps turn on. Interlock in pump starter turns basin heaters off. Tower supply valve is positioned to allow full water flow to bypass to the tower's water distribution system.

If the system temperature rises above the minimum control point, the tower supply valve is opened to allow full flow to the tower's water distribution system. If the system temperature continues to rise, the variable speed controller turns tower fans to minimum speed.

Note: During sub-freezing weather the minimum recommended speed for variable speed controllers is 50%. ALL FANS IN OPERATING CELLS OF MULTIPLE CELL TOWERS MUST BE CONTROLLED TOGETHER TO PREVENT ICING IN THE FANS.

If the system temperature continues to rise, then all fans in operating cells are increased, as required, up to full speed.

System Temperature Stabilizes

Control the tower leaving water temperature by modulating the fan speeds between 50 and 100%.

System Defrost Cycle

Periodically, all fans should be cycled off and then reversed at 50% fan speed allowing the system water temperature to rise and melt the ice that may have formed in the unit. Allow a time delay when switching from forward to reverse fan speed. Inspect the tower regularly during subfreezing temperatures to determine the frequency and length of the defrost cycle.

System Temperature Drops

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

NOTE: During extreme sub-frezing weather, it may be necessary to open the bypass valve upon fan shut down to prevent ice formation on air inlet louvers, if extended drip angles have not been provided.

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

System Off/ No Load

System pump turns off. Starter interlock energizes the basin heaters.
NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42ºF

APPENDIX D: Forced Draft Towers Two Speed Motor Control Sequence

System Off/ No Load

System pumps and fans off. Basin heaters cycle, as required, to maintain minimum water temperature (40°F).

System Temperature Rises

System pumps turn on. Interlock in pump starter turns heater off. Tower supply valve is positioned to allow full water flow to bypass the tower's 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's water distribution system.

If the system temperature continues to rise, the tower fan motor(s) is turned to low speed. In multiple cell units, the fans in each operating cell are turned to low speed. ALL OPERATING CELLS IN MULTIPLE CELL TOWERS MUST BE CONTROLLED TOGETHER TO PREVENT ICING IN THE BASIN.

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

System Temperature Stabilizes

Control the tower leaving water temperature by cycling fans between high and low speeds. Allow for a time delay when switching from high to low speed.

Scheduled Defrost Cycle

Periodically, all fans should be cycled off allowing the system water temperature to rise and melt the ice that may have formed in the unit. Inspect the tower regularly during sub-freezing temperatures to determine the frequency and length of the defrost cycle.

Fans should not be idle for long periods of time while water is flowing to the water distribution system, since condensate can form and eventually freeze on the fans and drive components which could lead to their failure when the tower is restarted. Cycle the fans periodically to prevent condensate from freezing and putting fans out of balance.

System Temperature Drop

If the system temperature drops to the 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 to bypass the tower's water distribution system.

System Off / No Load

System pump and tower fans turn off. Starter interlock energizes the basin heaters.

NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42°F

APPENDIX E: Forced Draft Towers: Variable Speed Fan Motor Control Sequence

System Off/ No Load

System pumps and fans off. Basin heaters cycle, as required, to maintain minimum basin water temperature (40°F)

System Temperature Rises

System pump turn on. Interlock in pump starter turns basin heaters off. Tower supply valve is positioned to allow full water flow to bypass the tower's water distribution system.

If the system temperature rises above the minimum control point, the tower supply valve is opened to allow full flow to the tower's water distribution system. Variable speed controller turns tower fans to minimum speed.

Note: During sub-freezing weather, forced draft modes should have a minimum 10% fan speed whenever water is directed to tower's water distribution system to prevent ice from forming on the fans and drive components. ALL OPERATING CELLS OF MULTIPLE CELL TOWERS MUST BE CONTROLLED TOGETHER TO PREVENT ICING IN THE BASIN.

If the system temperature continues to rise, then all fans in operating cells are increased, as required, up to full speed.

System Temperature Stabilizes

Control the tower leaving water temperature by modulating the fan speeds between 10 and 100%.

System Temperature Drop

Decrease fan speed, as required, down to 25% if the system temperature drops to a minimum control point the tower supply bypass valve opens to allow full flow to bypass the tower's water distribution system. Variable speed controller turns tower fans off.

System Off/No Load

System pump turns off. Starter interlock energizes the basin heaters.

NOTE: MINIMUM CONTROL POINT SHOULD NEVER BE LOWER THAN 42°F

APPENDIX F: System Design Guidelines

1. Early in the design phase of a project, the winter design loads and operating conditions for free cooling need to be established. Typically, the winter design loads are much smaller than those experienced during the summer. During the summer cooling season, the design range (entering minus leaving water temperature) and flow rate is greater than what is required for free cooling operation during winter. The design range for a typical summer air conditioning application is 10 degrees. However, when a cooling tower is used for free cooling, the heat of compression no longer needs to be absorbed. Therefore, the cooling range is reduced from 10 degrees to 8 degrees.

There are applications where the full load of the building may still need to be rejected by the cooling tower. Please note: Although the winter design loads are smaller than the summer design loads, it is more difficult for the cooling tower to satisfy the winder conditions. Please verify that the cooling tower will meet the winter design requirements. Contact the Evapco marketing department for assistance in selecting the proper cooling tower for your particular application.

2. When establishing the winter design conditions, do not specify very low leaving water temperatures. EVAPCO recommends a minimum leaving water temperature of 45 degrees.

3. Low flow conditions should be avoided. Flow rates should be as high as possible. Partial bypasses should NEVER be used during free cooling operation. The potential to form ice on the fill is greater when flow rates over the tower are reduced.

4. Cooling tower selection is very important. Although a single cell unit may meet the summer and winter design conditions, a multiple cell unit may be a better selection for winter operation. Since the winter design load is less than the summer load, it can be concentrated in fewer cells. A multiple cell unit allows the flow rate per cell to remain high, reducing the potential for ice to form in the unit. Multiple cell units also provide back up capacity if an operating cell were to fail.

5. The leaving water temperature should be monitored in all cells of multiple cell units. If the leaving water temperature of any particular cell drops too low, an alarm should be sent to the motor control center and all fans should be cycled off.

6. For most typical free cooling applications, standard unit construction will perform satisfactorily. However, for applications that experience very severe winter conditions, modifications to the cooling tower can be made to ensure better operation during free cooling. Accessories, such as basin heaters, electronic water level control, etc., can ensure that the cooling tower will function

properly during continued periods of very low ambient operation. Contact the Marketing Department for the optional unit accessories.

7. For applications that have continuous periods of free cooling operation in low ambient conditions, the control system design should include a defrost cycle. The defrost cycle allows the water running through the tower to warm up and melt the ice that has formed in the unit. Since defrost cycles include periods of time with pumps on and fans off, it is imperative that frequent tower inspections be done to determine their frequency and length.

8. For induced draft unit applications, where severe winter temperatures are experienced, additional means of ice management should be undertaken. The ability to reverse the fans at half speed is recommended. During very low ambient temperatures, reverse fan operation will melt the ice that has formed inside the unit and on the inlet louvers. Note that reverse fan operation requires reversing motor starters or variable frequency drives that can be programmed for reverse fan rotation.

9. For additional design assistance, contact EVAPCO's Marketing Department

APPENDIX G: System Operation Troubleshooting Guidelines

When an operational problem is encountered with a cooling tower operating in the winter, such as extreme ice build up, the following information should be obtained. Obtaining this information will help provide a solution to the particular problem.

1. First, determine where the ice has formed in the unit. Has it formed on the fill? This indicates low water flow. Inlet louvers? This indicates that fan(s) have been off for an extended period. Water distribution system, etc.? This indicates low water flow.

2. Determine what has happened to the cooling tower. Has there been a loss in cooling capacity? Has there been excessive vibration in the mechanical equipment? Have the overloads in the motors tripped?

3. Review the free cooling control sequence and determine the operating conditions of the cooling tower.
   - What is the operating sequence for the fan and pump control? Have any of the system parameters been inadvertently changed?
   - What type of application is the cooling tower used for? Is it an air conditioning or process application? Are the loads constant throughout the day or do they fluctuate?
   - What are the condenser water flow rates? What are the entering and leaving water temperatures?
   - What is the outside ambient temperature? Has it dropped significantly?
   - Have the sensing devices been located properly?

4. Review the layout of the cooling tower(s). Does the installation meet EVAPCO's recommended guidelines? What is the speed and direction of the prevailing winds? Are the prevailing winds causing recirculation?

5. Determine the condition of the cooling tower(s).
   - Has the cooling tower been kept clean?
   - Are there any clogged nozzles?
   - Are there any leaks in the unit?

6. Finally, determine whether the problem has been encountered in the past. Something that was done in the past may solve the current operational problem.

Several solutions to the common problems that are encountered with cooling towers operating during the winter are listed below. These guidelines can ensure that the ice formed in the units is maintained to manageable levels.

a. Concentrate the load in as few cells as possible to increase water loading in the operating cell. The higher the flow rate in the operating cell, the lower the potential for ice to form in it.

b. Cycle the fans periodically to allow the pumps to circulate water over the tower to help melt the ice that has formed in the unit.

c. For induced draft units only, incorporate reverse fan operation at low speed to reduce the levels of ice that may have formed on the inlet louvers.

For further assistance, contact EVAPCO's Marketing Department. EVAPCO has many years of experience in evaluating the operation of free cooling systems.