Cold Weather Operation of the Series 1500 Cooling Tower

Introduction

All cooling towers, whether crossflow or counterflow, can be successfully operated in all weather conditions if properly designed and operated per simple guidelines. Crossflow cooling towers, such as the Series 1500, are often preferred for the direct accessibility to key operating components and ability to visual inspect the heat transfer surface from points external to the tower during operation. These features are key to year around operation, especially in sub-freezing conditions. Unlike counterflow cooling towers, the Series 1500 does not require additional options or accessories to guard against crosswinds or to keep the air inlet louvers from icing in sub-freezing conditions. The single air inlet and crossflow design of the Series 1500 provide an optimal solution for operating in sub-freezing conditions as compared to a counterflow tower which will require additional accessories discussed above.

There are many benefits for operating cooling towers all year long, even in sub-freezing conditions. Rising energy costs, with a focus on the efficiency of the entire system, have increased opportunities for free cooling in system designs. For more detail, refer to "Minimizing Energy Costs with Free Cooling" on www.BaltimoreAircoil.com.

It is important to remember that with any cooling tower operating in sub-freezing conditions, water is being exposed to extreme, low temperatures. Careful attention must be taken during design to choose a layout to prevent air recirculation and select the proper basin freeze protection. During operation in sub-freezing conditions the capacity of the tower must be matched to the heat load by flow control and fan speed. It is also important to perform regular maintenance especially during sub-freezing conditions to verify the tower is performing as expected.

This document sets forth the guidelines for the successful cold weather operation of Series 1500 Cooling Towers.

Design and Installation

During the design phase of a project involving a cooling tower that will operate in subfreezing conditions, careful attention must be given to the following:

Equipment Layout

The primary consideration in laying out cooling towers for cold weather operation involves recirculation. Recirculation during warm weather operation results in some loss in tower capacity as the warm, moist discharge air recirculates to the air intakes of the cooling tower. During cold weather, recirculation can cause frosting and icing on surfaces around the equipment creating unsafe working conditions. Recirculation can also cause frosting and icing of the air inlet louvers on the tower which can eventually restrict air flow into the tower. Left unchecked, this icing could even damage the tower.

A proper layout, in accordance with the Series 1500 Layout Guidelines is imperative to successful cold weather operation. Please refer to "Series 1500 Layout Guidelines" on www.BaltimoreAircoil.com.

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Control Strategy

Successful cold weather operation will depend on the control strategy in place to account for the extreme climatic conditions. It is necessary to monitor and maintain the water and airflow within acceptable tolerances. Recommended methods are laid out in detail in the Operation section.

Operation

The tower capacity should always be matched to the load, especially in cold weather. As the heat load to the tower is reduced, the leaving water temperature from the tower will drop closer to the ambient temperature. In subfreezing ambient conditions freezing will occur if proper methods of capacity control are not set in place.

Cooling tower performance is a function of many variables including:

- Airflow rate
- Temperature difference between the ambient air and the water being cooled
- Heat transfer surface area

An increase in any of these variables will increase the heat transfer rate and, in the extreme, can lead to cooling the water to the freezing point. The closer the leaving water temperature approaches the freezing point, the greater the concern is for icing. On the Series 1500 Cooling Tower the area most susceptible to freezing is the outer face of the fill surface where air is initially drawn in, particularly near the bottom of the fill pack. Invariably, ice will form in this area first where the coldest air and water meet. Under such conditions, if steps are not taken to control the tower operation, ice build-up will continue to the point where the cooling tower may be damaged.

Capacity Control

There are three basic operational areas where close attention is required for proper cooling tower operation. Focus in these areas is important for operation in all conditions, but critical in subfreezing conditions:

- Water Flow Control
- Temperature settings
- Fan Control

Effective cooling tower icing control in sub-freezing ambient temperatures will require a combination of the three. The combination of controls employed on a given application depends upon the climatic extremes which are expected and the variations in heat load that will be encountered.

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Water Flow Control

The key focus for water flow control is to **operate the tower within the allowable flow range**.

Flow rates that are outside of the allowable flow range will promote increased scale formation during standard climatic conditions and increased ice formation during periods of operation below freezing. If not already known, your local BAC representative can provide the allowable flow range for your specific cooling tower.

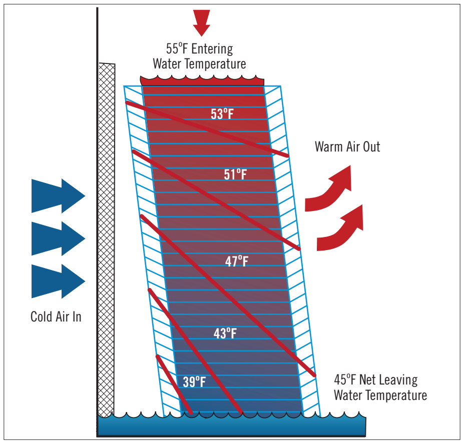

Figure 1.

Effect of Operating Above Maximum Flow Rate

If actual water flow is appreciably greater than design water flow, the water distribution basins may overflow. This overflow (splash out) can cause ice buildup on the exterior of the unit and areas surrounding the cooling tower.

Effect of Operating Below Minimum Flow Rate

This may cause water starvation within certain areas of the wet deck surface. Such areas are then very susceptible to icing at the wet / dry interfaces. This icing, which can occur inside the fill pack, can easily go unnoticed until the tower itself is damaged. Low flow conditions are usually encountered when pumps are taken out of service due to reduced plant load or when automatic by-pass systems are employed to maintain design water temperatures. Precautions should be taken so that the tower flow rate remains within the allowable range of the water distribution type. This can include cells taken out of service with the existing load distributed over as few cells as practical. This means complete shutoff of water flow to a cell, not just fan cycling.

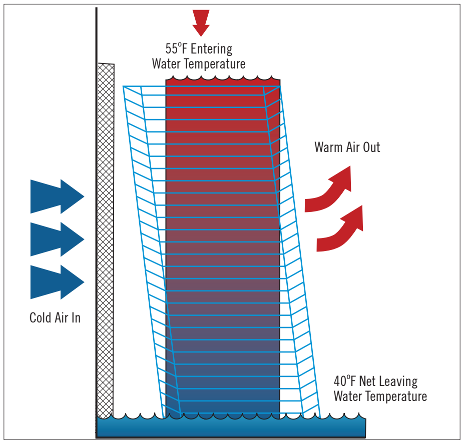

Figure 2.

CAUTION: When cells are taken out of service, always operate the last cell at the furthest end of the tower to prevent freezing the water at the end of the distribution header pipes.

A by-pass around the cooling tower is desirable for tower start-up and shut-down during sub-freezing temperatures, but great care must be taken when employing automatic by-pass valves for capacity control. These often can be useful in maintaining high water temperatures within the tower during operation and should be considered on jobs where wide variations in load are anticipated. However, **the control sequence is critical and under sub-freezing conditions the valves should not by-pass a flow amount that would reduce the flow to the tower below the minimal allowable flow rate. Units used in evaporative chilling (free cooling) applications should have full by-pass only, as a final step of control after fans are cycled off.**

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Temperature Setting

It is recommended that during sub-freezing temperatures, the tower be operated at the highest possible leaving water temperature that will be consistent with efficient system performance, but not less than 43°F.

As stated previously, when operating at sub-freezing temperatures, a cooling tower has the capability of producing leaving water temperatures appreciably below design. While this may be acceptable to the system served, extremely low leaving water temperatures will promote icing and should be avoided.

Higher leaving water temperatures will reduce the tendency of ice formation at the wet / dry interfaces in the cooling tower.

Fan Control

With cross flow operation, when the fan is operating, it's pulling water across the fill sheet towards the plenum. As mentioned prior, in subfreezing ambient, temperatures ice will form at the outer fill face first where the coldest air and water meet. Air is warmed as it moves across the fill pack picking up heat from the water which reduces the opportunity for ice formation inside the fill pack. See **Figure 1**.

Implementing the appropriate fan speed controls will keep the ice build on the outer face to an acceptable level:

Precise Airflow Control By Use of a VFD

Fan speed control provides the most common and most direct form of capacity control on cooling towers. When ambient temperatures fall below freezing, the tower can pull the leaving water temperature appreciably below design with full airflow. Fan speeds can be reduced with the use of variable frequency drives, pony motor systems, two speed motors, or by cycling off fans in some cells. Fan speed control by variable frequency drives is highly recommended for cold weather operation as it allows for more precise air flow and temperature control.

Implementing a Defrost Cycle

In subfreezing temperatures, ice may form on the outer face of the fill. Some ice formation is expected and unavoidable in cold weather conditions; the tower has been designed to tolerate this ice buildup. With crossflow designs, unlike many counterflow configurations, this ice is visible so that corrective action can be taken (ice often forms on the inside of counterflow inlet louvers where it is not visible until the airflow is completely blocked). In subfreezing conditions a defrost cycle should be implemented to avoid the ice from propagating too deep into the fill pack or from bridging across fill sheets and blocking airflow. Simply decreasing the airflow with a reduction in fan speed will reduce the volume of water being pulled across the fill pack towards the plenum section. This serves to flood the outer portion of the fill with warmer water and melt the ice that has initially formed. If the system is operating at the lowest recommended fan speed, the next step would be to turn the fan off for a period to allow the ice on the outer face to melt. See **Figure 2**.

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As a last resort, if ice has bridged the sheets in the fill pack or the combined inlet shields, operating the fan in reverse at low speed (no more than 25% of full speed) will serve to deice the surface. This method should be used sparingly due to the risk of fan failure and resulting personal injury due to ice formation on fan blades, fan stacks, or eliminators. The fan speed should be kept low in the reverse direction to keep water from being forced out of the cooling tower louver face and causing ice buildup on the exterior of the unit or areas surrounding the cooling tower. Fans must not be operated in reverse for extended periods. In instances where fan reversal is required, a time delay of at least 40 seconds between forward and reverse must be incorporated into the controls to avoid damage to the drive system. It is also recommended that cooling towers operated in sub-freezing weather be equipped with fan vibration cut-out switches as a safety precaution especially on units which will use reverse fan operation for ice control.

The proper implementation of a defrost cycle will serve to keep ice formation to a minimum. Depending on the complexity of the system, this can be done manually or automated. If automated, periodic observations (several times daily) are still required to ensure that the operating strategy is successful and that the deicing period is at the required frequency. The frequency of inspections should increase with a decrease in ambient temperatures. Low cost, remote cameras connected to the control system have been used successfully for remote monitoring of cooling towers in such conditions.

Start-Up and Shut-Down

The most critical periods of operation at sub-freezing temperatures are tower start-up and shut-down, since the heat input to the tower is usually minimal at these times. Operators need to pay close attention to their towers during these periods.

Some systems can benefit from the installation of a full flow water by-pass such that water can be circulated through the system without going over the tower. On start-up, the by-pass is used until the temperature of water entering the tower rises to within 5°F of the maximum tolerable temperature for the system. Once this level is reached, the by-pass is closed and the full water flow is put over the cooling tower while the fans remain off.

If provision for by-pass is not included in the tower system design, the circulating pumps should not be started until the last possible moment consistent with plant operation. Tower fans should not be turned on until the circulating water temperature leaving the tower reaches approximately 5°F below the maximum tolerable temperature for the system. At this point, all fans should be staged on, starting on the lowest speed and ramping up in unison as needed to meet the design leaving water temperature setpoint.

The recommended shut-down procedure is essentially the reverse of the start-up procedure. As the load drops, fans are cycled simultaneously for evaporative chilling applications to maintain the recommended tower leaving water temperature. Once all fans are off, a by-pass should be employed with no water over the tower at the earliest possible moment. On systems with no by-pass provision, the tower pump(s) should be stopped as soon as temperatures in the tower drop below the recommended minimum or as soon as possible thereafter consistent with the cooling needs of the system.

WARNING: In sub-freezing weather, under no circumstances should the cooling tower operate for extended periods without a heat load.

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Pan Water Protection

All towers operating at sub-freezing temperature, except those located indoors in a heated space, must have some means of protecting the pan water from freeze-up when the tower is idle. Common means of providing such protection include remote sumps, or electric pan heaters. Note that the remote sump option eliminates the possibility of freeze-up due to a heater malfunction and also, if properly designed, precludes the need for heat tracing and insulating portions of the supply piping, return piping, and make-up lines.

Maintenance

Maintenance is particularly important on cooling towers that will be operated in sub-freezing weather to ensure against problems which can cause icing.

First and foremost, frequent visual inspections of the tower must be performed on a regular basis to:

- Ensure that the method of ice control is effective.
- Ensure that all controls are set properly and functioning normally.
- Discover any icing conditions before they develop to the point where the tower or supports are damaged or the system performance is impaired.

Additionally, a regular preventive maintenance schedule must be established and carried out, despite adverse weather conditions. Items covered should include:

- Regular lubrication of bearings with the proper type grease as indicated on the unit lubrication plate.
- Regular cleaning of strainers to prevent excessively high water levels in the pan.
- Regular checking and adjustment of the make-up water float valve to assure correct water levels in the pan.
- The complete Operation & Maintenance Manual for the Series 1500 can be found at www.BaltimoreAircoil.com.

Conclusion

Induced draft, crossflow towers such as the Series 1500 Cooling Tower can be successfully operated in sub-freezing temperatures when proper operating methods and controls, along with a routine maintenance program as outline above, are followed.

REFERENCE:

1. Laboratory Test Report: "The Effect of Scale Formation on Heat Transfer Coils."

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