COLD WEATHER OPERATION OF COUNTERFLOW COOLING TOWERS

Typically, ice forms in a cooling tower in accordance with the following guidelines.

- **The potential for ice varies *inversely* with outside air temperatures.** A **decrease** in air temperature will **increase** the probability of ice formation.

- **Within design limits, the potential for ice varies *inversely* with the amount of water flowing over the fill.** A **decrease** in water flow rate will **increase** the probability of ice formation.

- **The potential for ice varies *directly* with the volume of air flowing through the tower.** A **decrease** in air flow will **decrease** the probability of ice formation.

- **When air flow is controlled to maintain a specific cold water temperature, the potential for ice varies *inversely* with heat load.** A **decrease** in heat load and/or a **decrease** in the required cold water temperature will **increase** the probability of ice formation.

Ice forming characteristics on any given tower vary depending on ambient wet bulb, wind velocity, circulating water rate, and heat load. The key to minimizing or eliminating ice formation in any cooling tower is skillful manipulation of heat load, water flow, and fan controls, so that the circulating water temperature in the fill area remains in a range which will discourage ice formation. Utilization of any or all of these methods of control depends on the climatic conditions that occur at the tower site, the cycling requirements of the plant, and the thermal and mechanical design of the tower. Although the formation of a strict set of guidelines which pertain to every application cannot be made, the following generalizations based on the operating parameters of the tower provide a good starting point for the development of a site-specific operating procedure aimed at minimizing ice formation.

GENERAL COMMENTS •

The control of ice buildup on cooling towers is extremely important. Due to the nature of Counterflow tower designs, heavy ice accumulation on members of the tower can be realized during severe winter operation if proper operation is not adhered to. The operator should be prepared to closely supervise winter operations.

Ice damage can be a common occurrence to towers subject to severe winter weather conditions. Cooling tower live loads, due to icing, can become large. It is a question of the Operator exercising good winter operation control to prevent any abnormal ice buildup and damage. Basically, this is accomplished by maintaining minimum heat loads, cycling fans on and off (or reversing fans to full and/or half speed), observing cold water basin temperatures and tower icing conditions. The following sections go into more detail on the control of temperature, water, fans, startup and shutdown. The most important fact to remember is: **Learn to identify your own individual needs with respect to winter operation control.** Towers will exhibit different characteristics on icing and these depend on operating levels, tower designs, placement and orientation relative to buildings and prevailing winds, and Operator's initiative to monitor tower's cold weather operation and implement proper and timely control measures to minimize ice buildup.

BASIC CONSIDERATIONS •

A cooling tower is a unique heat exchanger in that both convective heat transfer and mass transfer of water vapor (evaporation) are involved in the heat exchange process. The transfer surface is established by direct contact between water and the tower air flow. The heat transfer rate is fundamentally dependant on; (a) air flow rate, (b) local temperature differences between water and air, and (c) heat transfer surface area.

An increase in any of these variables will increase the heat transfer rate. If atmospheric temperatures are below freezing and the heat transfer rate is sufficiently high at any point within the tower, localized ice formation will occur. If steps are not taken to modify one or all of the basic operational variables, ice will continue to form and ice build-up will be noted if water is continuously supplied to the affected area.

Ice damage to a cooling tower can be avoided during cold weather operation if proper operating methods are established and diligently followed. On a counterflow cooling tower the most susceptible areas for ice formation are the air intake area and bottom portions of the fill. Ice will form in these areas first. The basic louver design configuration of a counterflow tower makes it less susceptible to ice problems as compared with other designs. Ice formation will depend on a number of factors, most important of which are (a) ambient temperature, (b) wind speed, direction and its persistence, (c) operating water temperatures, and (d) air and water flow rates.

It becomes clear that no simple operating procedure can be established that will insure ice control for all possible combinations of these variables. Because of this **there is no substitution for frequent visual inspection of the tower until enough operating experience has been gained to verify that a specific operating mode is effective for a given set of load and ambient conditions.**

CONTROL METHODS •

There are three basic operational methods that will effectively control ice. The extent and duration to which each must be applied will depend on: (a) the operational flexibility of the cooling tower fan and water flow control systems which are part of the tower and plant design, (b) the climatic extremes that can be expected at the plant site, and (c) basic heat load and load cycling requirements anticipated for the unit. The following guidelines are offered as an aid to help the owner establish optimum cold weather operating procedures.

Fan Operation •

The simplest, most direct and effective ice control can be achieved through variations in fan operation. At ambient temperatures below freezing, the tower water return temperature is usually substantially below the temperature required for efficient plan operation. Thus, full air flow to all cells is not required from a plant performance standpoint. When a fan operates at half speed,[1] the airflow is reduced to half at one-eight the full speed horsepower requirement. If the fan is turned off, the cell acts as a natural draft tower and the air flow usually diminishes to less than one quarter of full speed flow (in some cases approaching zero).

In either case, reduced air flow will substantially reduce the heat transfer rate and operating temperatures will rise. All of these factors reduce or eliminate the tendency for ice formation.

The fans may also be operated at either half speed or full speed in reverse. Standard fan, gear and motor units supplied with most cooling towers are designed to operate in this mode without creating any mechanical or electrical overloads. With the fans operating in reverse, air flow is reversed. Thus, heated air is supplied to the fill and louver area which further improves ice removal capabilities. Fan reverse operation has proven to be an effective ice control method at several Canadian locations where weather conditions are much more severe than is usually encountered in the continental United States. Under severe cold weather conditions, (below zero degrees F) the normal procedure is to operate each individual fan in reverse for a period of from fifteen to twenty minutes and to repeat this cycle once every two to three hours. A simple automatic deicing control system would be as follows: One switch would start the automatic deicing system which would sequence each fan or group of fans in reverse operation. The automatic system should have an adequate time delay between forward and reverse fan operation. This would allow the control room operator to deice each cell independently for an extended period of time if visual inspection showed that a localized icing problem existed after the automatic deicing cycle. Fans should not be operated in reverse for extended periods since ice can form on fan blades, fan stacks, or drift eliminators and may cause damage. For this reason, the maximum recommended time interval for fan reverse operation is thirty minutes per reverse operation cycle.

Temperature Control •

During sub-freezing winter periods, the cooling tower will normally produce a return water temperature below that required for efficient plant operation. Higher operating temperatures will improve ice control capabilities since more heat must be removed from the water before ice will form. Thus, there is less tendency for ice formation in critical areas, if higher operating water temperatures are maintained. The coldest water temperature occurs at the lower portion of the fill adjacent to the air intake opening. Operating at higher water temperature reduces ice formation tendencies in this area and at the same time the fan reversal ice control method will be more effective. For these reasons, it is recommended that the tower be operated during sub-freezing weather at the highest possible cold water temperature that is consistent with efficient plant operation. This can be accomplished by reducing fan speed or turning fans off. If fans are turned off to control operating temperatures, each fan should be off for approximately the same time interval. This is advantageous both for deicing and for accumulating approximately equal operating hours on each set of mechanical equipment.

Water Flow Control •

Water flow control is an important part of winter operation. There is one water flow condition that should be avoided during sub-freezing weather.

If for some reason water flow to the tower is substantially in excess of the system design flow rate, the water may not stay within the confines of the water distribution system and intermittent splash out or leakage may result. This may cause localized ice buildup since a continuous and/or sufficient source of heat is not available to eliminate ice. Overflow conditions normally do not occur since standard tower water distribution systems are designed to handle a minimum of 110% of the design water flow rate. However, if the pump system is over designed, over pumping can be avoided by throttling pump operation. This should be done by partially closing a valve (or valves) in the main circulating water piping system after the pumps.

Care should be taken to avoid water flow rates to any cell that are below the minimum tower water distribution system design level since this may result in water starvation to certain areas within the fill area. This can cause localized icing problems. Low flow conditions are usually encountered when pumps are out of service. If a pump is out of service for an extended period and visual inspection shows that ice formation cannot be controlled by fan operation, cells should be taken out of service. This means complete shutoff of water flow to the cell. If cells must be taken out of service, always operate the last cell in the tower to avoid freezing the water at the end of the distribution header pipe.

Note: Tower installations with multiple pumps can benefit from turning off a pump and cells as required to keep the water and heat rate as high as possible (without over pumping or overflowing) on the cells that remain in service. This will raise the water temperature to assist in keeping ice from forming.

Installation of Ice Screens at the Air Inlets •

Ice screens installed in the air inlet areas have been shown to effectively control ice buildup on the louvers, louver support members and tie lines within the air inlet areas. They are simply sections of stainless steel, welded wire mesh in a 2" x 2" pattern attached at the top of the air inlet to the longitudinal tie line and attached to the inside face of the columns and lower longitudinal ties above the waterline. The mesh allows a drip surface for the water and as it freezes it forms a pane of water usually ½" to ¾" thick that will eventually close off most if not all of the air inlet area. While this "pane" blocks the airflow, the airflow is not needed during the cold months anyway. *The pane keeps splash out from getting to the louvers protecting them from ice formation.* As the temperature rises the ice of the pane melts away and normal airflow resumes. Ice screens are relatively inexpensive to install, and they self-regulate themselves making them easy to maintain. Midwest Cooling Tower's has installed these with excellent results on many counterflow cooling towers. See our brochure on our website at www.mwcooling.com.

COOLING TOWER INSPECTION •

One of the most vital elements of reducing ice formation in a cooling tower during cold weather operation is operator knowledge of the physical condition of the tower through continuous inspection. Regardless of which control methods are used, a cooling tower cannot be safely operated at ambient conditions below freezing without visual inspection. Most major cases of ice damage can be avoided by timely tower inspection. Inspection of the tower should begin when the ambient temperature falls below 40°F. The frequency of inspection should be every four hours. At ambient temperatures below 32°F, this frequency should be increased to every two hours. Whenever fans are being cycled, the tower should be inspected hourly. When changes in the hydraulic mode of operation are required, i.e. water flow is shut off to certain cells, the operator should visually check the isolated cells to be sure they do not have water leaking into the fill section. A small amount of water leaking into an inactive cell may result in extensive ice damage.

COLD WEATHER STARTUP AND SHUTDOWN•

A cooling tower is most susceptible to ice damage during unit startup and shutdown operations since during these periods there is a minimal heat load on the tower. Temperature control is the key to successful operation under light load conditions.

Startup •

Positive startup/shutdown cold weather control can be obtained by designing a water bypass into the circulating water piping system such that the water may be circulated through the system without going over the tower. On startup, the bypass is used until the water temperature is above 80° F[2]. As the temperature rises above this level, the bypass is closed and the full water flow is put over the tower. The bypass may then be partially opened to keep the operating temperatures up provided the bypass flow is such that minimum water flow to the tower is equal to, or greater than, the minimum distribution system design level. A bypass is recommended on any system where extensive unit cycling or light load is anticipated during cold weather extremes on a regular basis.

If a bypass is not included in the circulation water system, pumps should not be started until the last possible moment consistent with plant operation. All fans should be left off until the circulating water temperature is above 80° F[2]. Then initiate fan operations, one at a time, as load is increased. On startup, heat load should be increased as rapidly as possible until minimum recommended operating water temperatures are achieved.

Shutdown •

The shutdown procedure is essentially the reverse of the startup procedure. As load is decreased, turn off fans to maintain return water temperatures above 80° F[2]. When all fans are off, partially open the bypass. Operate with full bypass and no water over the tower at the earliest possible moment. If no bypass is available, discontinue circulating water over the tower when temperatures fall below minimum recommended levels or when other equipment has cooled to acceptable temperatures. **Never operate the tower without heat load in sub-freezing weather for an extended time period. Frequent visual inspection during startup and shutdown is vital if icing problems are to be avoided.**

1. There should be a minimum thirty second time delay before initiating half speed motor operation when the motor is operating at full speed. This will avoid high torque overload on the mechanical equipment which can occur if half speed operation is initiated before the fan has decelerated to half speed or less.

2. Higher minimum temperatures should be used if ambient temperatures are below –20° F and wind speeds are above 15 mph. A minimum water temperature of 70° F is satisfactory if ambient temperatures are above 0° F and wind speed is below 15 mph.