Winter operation of mechanical-draught cooling towers

B F A Cabral discusses how low ambient air temperatures affect the performance of mechanical-draught cooling towers, and the precautions necessary to prevent icing, etc

Operation of mechanical-draught cooling towers during the winter months must take into consideration the effect of low ambient air temperatures on the tower performance.

Mechanical-draught evaporative cooling towers are direct contact devices, and the heat transfer mechanisms involve both sensible heat and mass transfer. Consequently, the effects of low ambient air temperatures are not as would occur with a device such as an air blast cooler, in which only sensible heat transfer takes place. In cooling towers, the one property of the ambient air having a significant effect on the cooling performance (for a given air mass flowrate) is the ambient air wet bulb temperature.

In some cooling systems water leaving the tower well below the design temperature can be a disadvantage. In others, low water temperatures are not disadvantageous but are unnecessary and power can be saved in various ways if thermostatic control of the water temperature is employed. Figure 1 shows the extent to which air flowrate through the tower can be reduced, whilst maintaining the design water temperatures, as the ambient air wet bulb temperature falls. The power required would be approximately proportional to the cube of the air flowrate.

There are other systems where there are advantages to be gained from the lower water temperatures produced during periods of low ambient air temperatures. In such cases it is of interest to the system designer to know what the temperatures will be. Figure 2 shows how the temperature of the water leaving the tower varies with ambient air wet bulb temperature.

During low ambient air temperatures conditions the cooling load on the tower can be increased by increasing the cooling range (i.e. the difference between inlet and outlet water temperatures) whilst maintaining the design water flowrate and design exit water temperature. This could be of practical interest if it were planned to pass cooling water through a number of processes in series so as to release another tower for maintenance or inspection. Figure 3 shows how the range can be increased, whilst maintaining the off-tower water temperature, as the ambient air wet bulb temperature falls.

During times of low ambient air temperatures the water flowrate through the tower can be increased whilst maintaining the design on and off-tower water temperatures (i.e. maintaining the design cooling range). This would be of practical interest if the water flow from another tower were to be added to the design water flowrate so as to release the other tower for maintenance or inspection. (This would only be possible, in fact, if the water distribution system could deal satisfactorily with the increased water flowrate). Figure 4 shows how the water flowrate can be increased, whilst maintaining the design cooling range and design off-tower water temperature.

It should be pointed out that in the calculations which produced Figures 1 to 4, typical design cooling duties have been used. If other design cooling duties were assumed then the relationships would not be identical. However, the curves give a good indication of the sort of results to be expected.

Obviously a cooling tower should

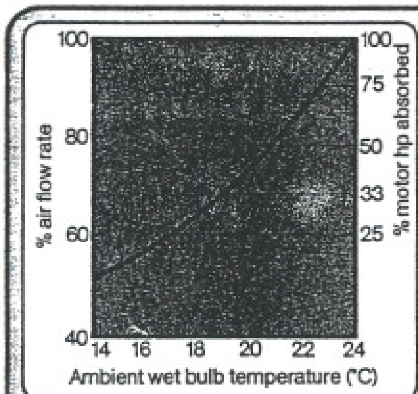


Figure 1. Reduction of air flowrate with fall in ambient air wet bulb temperature. Liquid loading—200 gal/hr ft² (9.7 m³/hr m²); cooling range—8.3°C; recooled water temperature—27.8°C; altitude up to 1,000 ft (300 m) above sea level

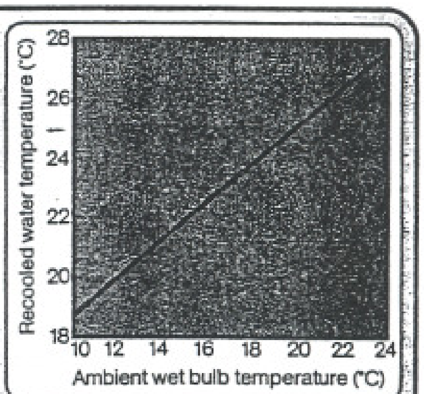


Figure 2. How the temperature of water leaving a cooling tower varies with ambient air wet bulb temperature. Liquid loading—200 gal/hr ft² (9.7 m³/hr m²); cooling range—8.3°C; air face velocity—500 ft/min (2.5 m/sec); altitude up to 1,000 ft (300 m) ASL

Figure 3. How the cooling range of a tower varies with ambient air wet bulb temperature. Liquid loading—200 gal/hr ft² (9.7 m³/hr m²); air face velocity—500 ft/min (2.5 m/sec); altitude up to 1,000 ft (300 m) above sea level

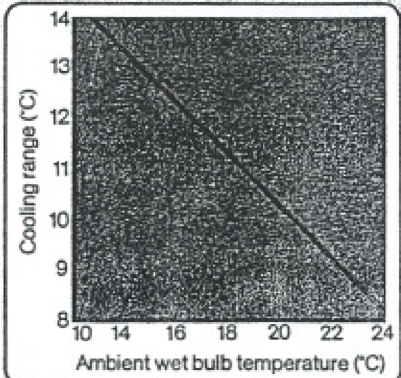
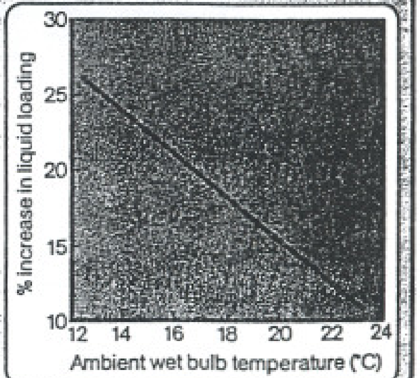


Figure 4. How water flowrate can be increased with fall in ambient air wet bulb temperature. Liquid loading at 24°C wet-bulb—200 gal/hr ft² (9.7 m³/hr m²); cooling range—8.3°C; other conditions as in Figure 2



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be designed to ensure an efficient performance without excessive maintenance work. Nevertheless, no item of industrial equipment or plant can function indefinitely without maintenance. Certainly, failure to regularly maintain cooling towers inevitably results in reduced cooling performance, and often more rapid deterioration than necessary of the tower structure and internals.

Maintenance

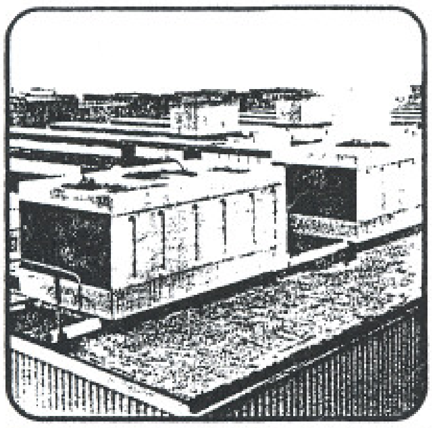
Frequently, during the planning and design stage of a project, much time is spent deciding the precise water temperatures which should be used to select the cooling tower. Ironically, once the system is installed and commissioned, the cooling tower maintenance is often badly neglected and the resulting water temperature can be many degrees above that envisaged by the designers. This can have various important results, depending upon the equipment being served.

The most insidious effect could well be the excessive deterioration of the cooled equipment due to its operating above its specified cooling water temperatures. Another result of high water temperatures could well be loss of production as machines or processes have to be slowed down to low rates of heat dissipation by the cooling system.

Maintenance of cooling tower is often neglected during the winter, as the required recooled water temperature is often easily attained even if the tower is operating relatively inefficiently. This often leads to an unpleasant surprise as the weather gets warmer. This is particularly so if the tower cooling load also increases as, for example, with refrigeration equipment serving an air conditioning system. It is advisable, therefore, not to neglect inspection and, where necessary, maintenance of a cooling tower during the winter. In fact, it is good practice to inspect the tower during the Christmas shutdown, carrying out any rectification work indicated during the Easter shutdown. A possible alternative is an inspection at Easter with rectification work being carried out at Whitsun.

In winter, low ambient air wet bulb temperatures mean that lower recooled water temperatures can be obtained. With rare exceptions the lower water temperatures are not required by the process being cooled.

Sometimes (for example refrigeration equipment) water which is too far below design temperature can cause difficulties in operation. In addition, maintaining a lower water temperature than is essential results in more power consumption than necessary. It is usual, therefore, to limit the fall in water temperature by controlling the air flowrate through the tower.



Two Carter Lo-Line GRP cooling towers on the roof of Ford's Halewood factory

The simplest method of controlling the re-cooled water temperature is on/off control of the fan by means of a thermostat with a sensing element in the water leaving the tower. This method is the usual practice with small to medium-sized towers.

Another relatively simple method of control is to use a two-speed motor, together with a two-step thermostat the fan at high speed, low speed, and off as required. This gives better water temperature control and reduces the number of motor starts.

Small to medium-sized towers (both forced and induced-draught) have been designed with a damper to vary the air flow through the tower. This is, in theory, a relatively inexpensive method of obtaining close control of the water temperature. However, although various designs of damper have been used, reliability, in practice, has often proved to be very poor. Very large towers, particularly multicell ones, have been designed using a frequency changer to produce infinitely-variable fan speed, thus achieving very close control of recooled water temperature and maximum saving.

Icing

In the UK icing is not usually a severe or persistent problem, particularly if sensible precautions are taken. Icing of the packing must be avoided in all types of tower. Some types of packing are more resistant to icing than others, but all types suffer damage if the icing is severe enought.

There are various precautions which minimise the danger of icing. First, and obviously, the fan should not be run if there is no cooling load. Secondly, if there is no cooling load, it is better to shut off the water flow completely or, if that is not possible or desirable, keep the water flowrate at maximum. The danger of icing is increased if very small water flowrates are maintained. In fact if this occurs whilst the fan is running, severe icing is virtually certain, even at air temperatures only slightly below freezing point.

In packaged towers, an immersion heater, usually electric, is almost always fitted in the base tank, close to the water outlet to prevent icing-up. Electric immersion heaters are fitted with a thermostat which switches on the heater just above freezing point.

With induced-draught towers there is a possibility of icicles forming from the top of the air inlets. In some large towers piping arrangements have been fitted to by-pass the tower packing and thus distribute warm water over the inside face of the air inlets.

A fan operating in a forced-draught tower is subject to the risk of freezing. Icing is a particular danger as this can form not only on the fan blades but also the inlet guard. Ice particles can be thrown off outside the casing, and, under extreme conditions, could cause severe damage to outside plant or personnel. The fan casing should be designed so that any water entering it (either from the tower or external sources) can drain away. If water is allowed to collect in the fan casing the fan could be frozen into place. This could result in damage to the drive system if starting were attempted.

Low-temperature starting

An axial-flow fan running at a constant speed and with an unchanged airflow system maintains a constant volumetric air flowrate. If a tower fan runs in winter, particularly with little or no load, the increased air density results in a greater absorbed horsepower (basically because a greater mass of air is being moved). In addition, with large induced-draught towers with axial-flow fans the drive is always via a gearbox. In very cold conditions the gearbox oil has a higher viscosity, thus increasing the horsepower absorbed by the gearbox. An electric motor of quite adequate rating for starting under design conditions may therefore be inadequate for very cold weather starts. So it is prudent to feather the fan blades if it is necessary to test run the fan at very low ambient conditions and with little or no heat load. It is not normally considered good practice to rate the motor specifically for cold weather starts. ☐

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