COOLING TOWERS

Cooling towers use the principle of evaporative or 'wet bulb' cooling in order to cool water.
The main advantages over a conventional heat-exchanger are:

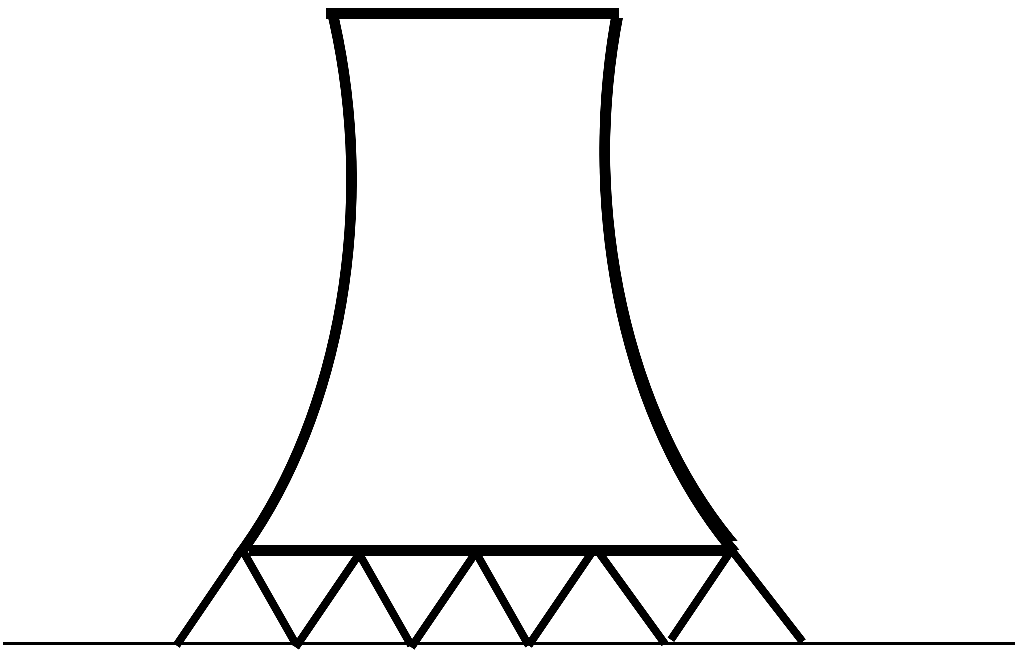
** they can achieve water temperatures *below* the temperature of the air used to cool it.

** they are smaller and cheaper for the same cooling load.

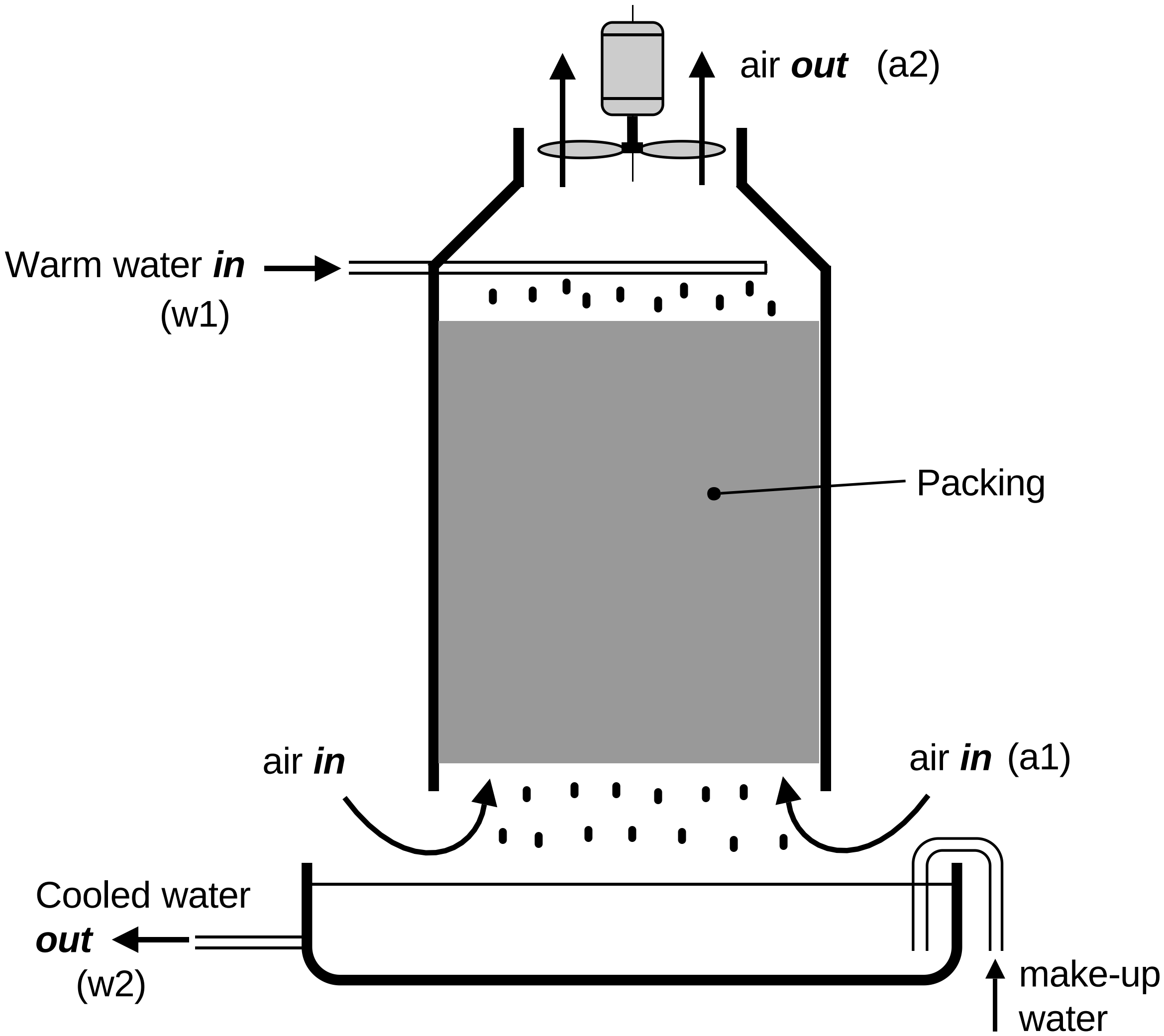
The main disadvantage of cooling towers is their need for careful maintenance to minimise the risk of water fouling and water-borne organisms e.g. Legionnaire's disease.

There are two main types of cooling tower: ***forced draught*** and ***natural draught***. However, their principles of operation are identical.

The latter typically have a characteristic waisted design:



Forced draught cooling tower



From continuity:

$$\dot{m}_{a1} = \dot{m}_{a2} = \dot{m}_a \qquad \text{(dry air)}$$

$$\dot{m}_{w1} + \omega_{a1}\dot{m}_a = \dot{m}_{w2} + \omega_{a2}\dot{m}_a \qquad \text{(water)}$$

$$\dot{m}_{w1} - \dot{m}_{w2} = \dot{m}_a\left(\omega_{a2} - \omega_{a1}\right)$$

The difference in water flows has to be 'made up' by 'make up' water.

Energy:-

$$\dot{m}_{w1}h_{w1} + \dot{m}_a h_{a1} = \dot{m}_{w2}h_{w2} + \dot{m}_a h_{a2}$$

$$\therefore \quad \dot{m}_{w1}h_{w1} - \dot{m}_{w2}h_{w2} = \dot{m}_a(h_{a2} - h_{a1})$$

The amount of water lost by evaporation is typically only a very small percentage of the water inlet flow, therefore :-

$$\dot{m}_{w1}Cp_w(t_{w1} - t_{w2}) \approx \dot{m}_a(h_{a2} - h_{a1})$$

Conditions within the cooling tower are typically such that the emerging air is very close to 100% saturated.

The aim of a cooling tower is to cool water to the maximum extent. It therefore needs to be kept in contact with the air for as long as possible. In theory the minimum water temperature that can be achieved is the wet bulb temperature of the incoming air. However, a tower would have to be made unduly tall to achieve this. A reasonable limit is to achieve a temperature within 5 to 8K of the wet bulb temperature.

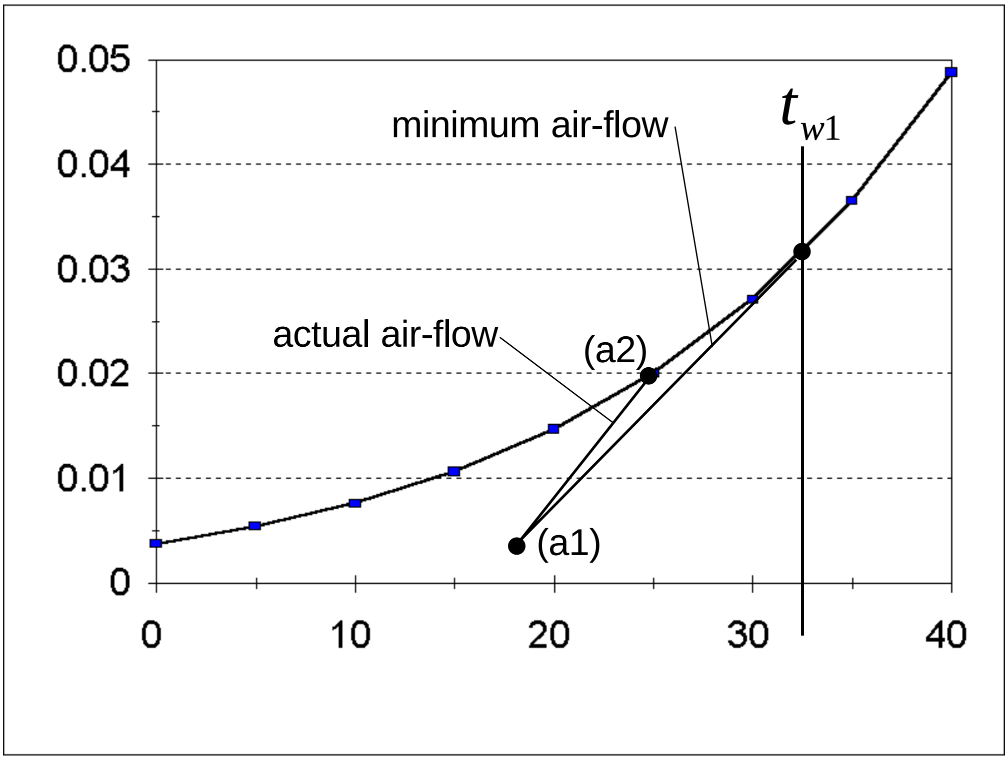
Cooling Tower design/performance

A tower would normally be designed to remove a given amount heat per unit time from a given flow rate of water

For a given condition of the inlet air (d.b. temp. & %sat) the wet bulb temperature can found, and a lower limit for the water exit temperature determined.

Given the water flow rate and energy removal rate the inlet temperature of the water may be found.

The absolute minimum air-flow required is found by assuming the air becomes 100% saturated with the *same* exit temperature as the water inlet.
Again, for this condition to be met would imply a very tall tower, so actual air flows will be some 20-40% higher than this minimum.



(Ref. Cooling Towers - Principles and Practice, GB Hill, EJ Pring, PD Osborn : Butterworth-Heinemann 3rd ed.)