Exercise 1

The following data are known from an tower cooling:

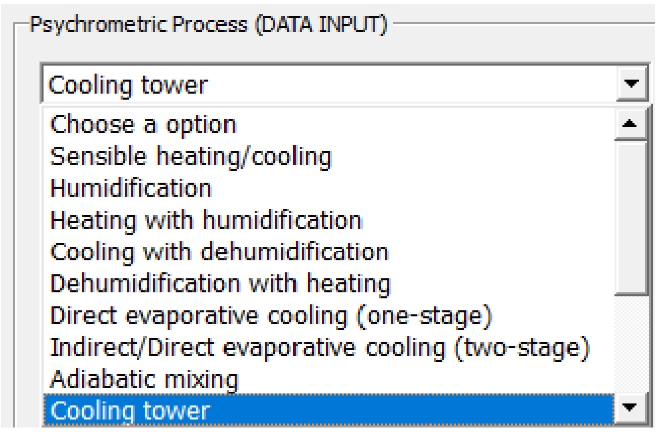
Dry bulb temperature (state 1): 28.0 ºC Relative humidity (state 1): 35.0 %
Dry bulb temperature (state 2): 31.0 ºC Relative humidity (state 2): 99.0 %

Inside temperature water: 40.0 ºC
Approach: 6.0 ºC
Water mass flow: 27.77 kg/s

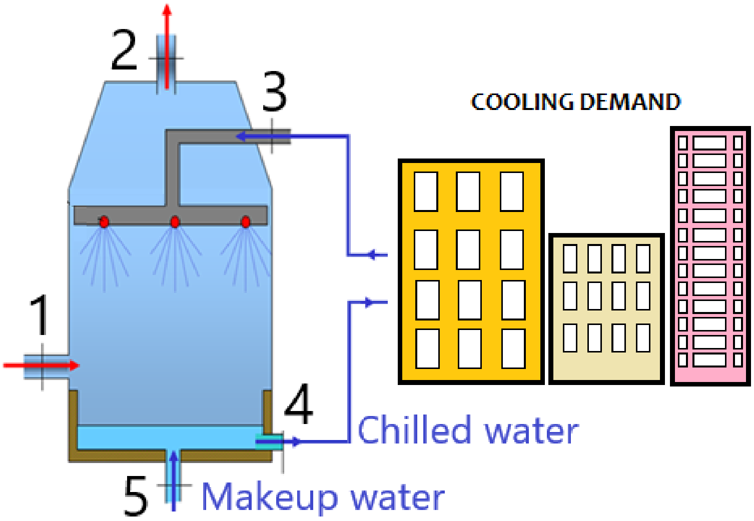
Site elevation: Sea level
Dead state: 101325 Pa, 4ºC, 70%

A cooling tower is a specialized heat exchanger in which air and water are brought into direct contact with each other in order to reduce the water's temperature. As this occurs, a small volume of water is evaporated, reducing the temperature of the water being circulated through the tower. he cooled water is then pumped back to the condenser or process equipment where it absorbs heat. It will then be pumped back to the cooling tower to be cooled once again. The air can be pulled by an motor-driven electric "cooling tower fan".

THERMOPsychro Software: PROPERTIES OF HUMID AIR -AIR CONDITIONING PROCESSES



Many power plants and other industrial facilities utilize open recirculating cooling systems equipped with cooling towers for heat transfer from condensers and other heat exchangers. Many nuclear power plants have once-through cooling (OTC), since their location is not at all determined by the source of the fuel, and depends first on where the power is needed and secondly on water availability for cooling. Using seawater means that higher-grade materials must be used to prevent corrosion, but cooling is often more efficient.



INFORMATION

- It is possible to determine the mass flow rate of dry air (the complete thermodynamic state of the humid air at the outlet must be defined) or
- To obtain the mass flow water of circulation (the complete thermodynamic state of the humid air at the outlet must be defined) or
- To obtain the thermodynamic state at the outlet of the air (both mass flows rate of dry air and water must be known).

Approach: Difference between the leaving water temperature and entering air wet-bulb temperature.

Power consumption:
- Induced draft: A mechanical draft tower with a fan at the discharge (at the top) which pulls air up through the tower.
- Forced draft: A mechanical draft tower with a blower type fan at the intake.

OK

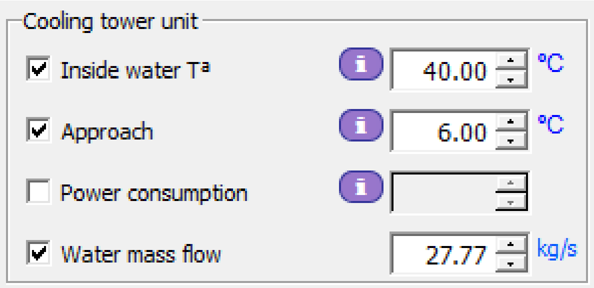
APROACH

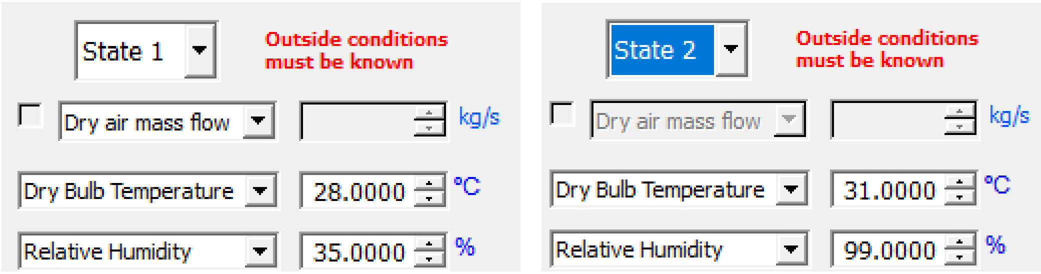
Difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature.

OK

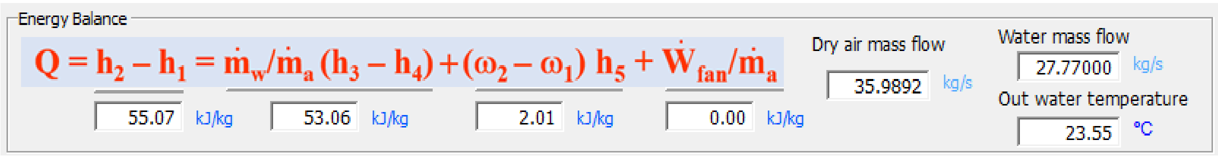
- Get the dry air flow

Choose the case to solve:
- Get the dry air flow
- Get the water mass flow





The first step is to determine the energy balance around the tower.



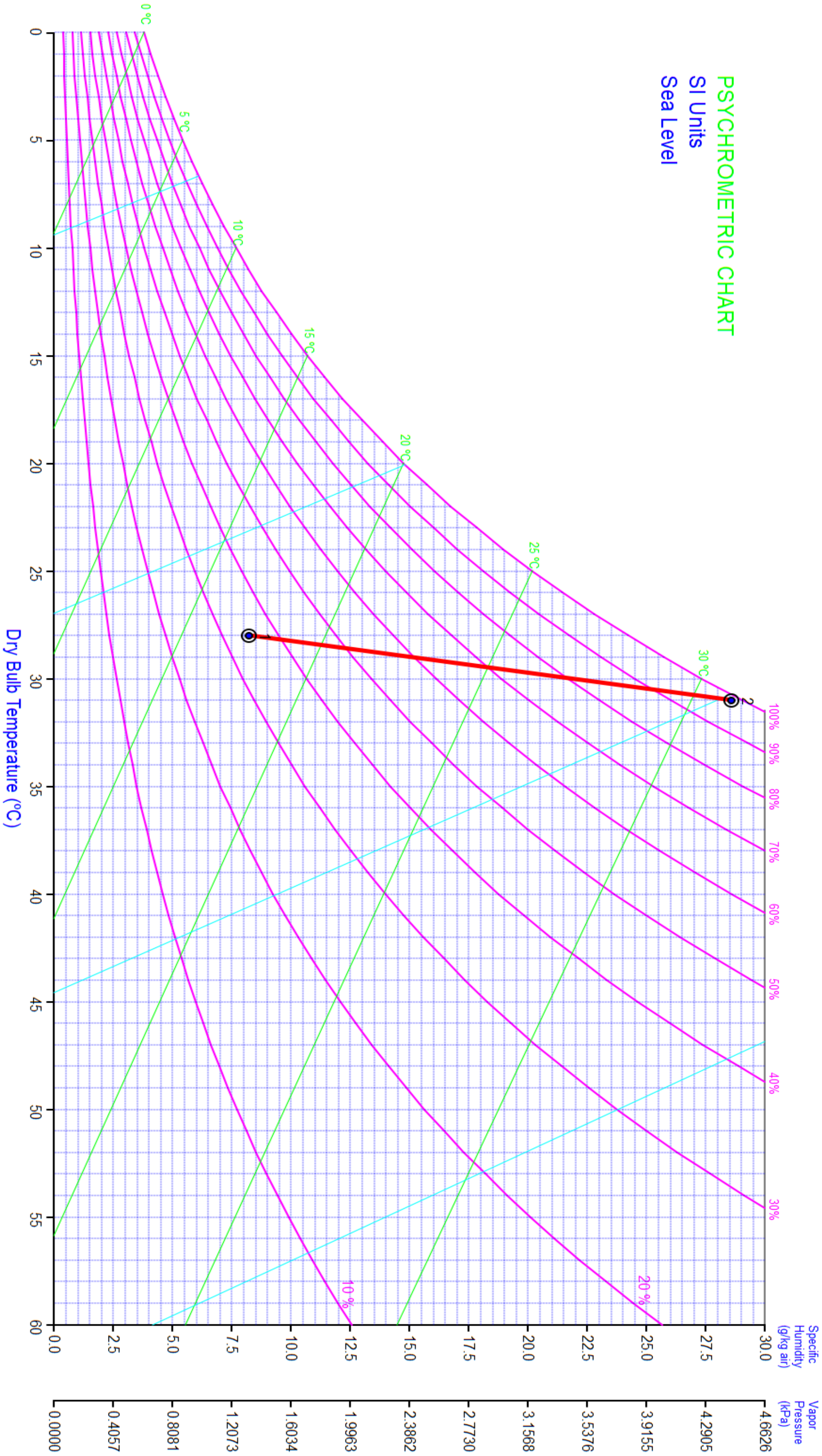
So, with an inlet cooling water flow rate of 27.27 kg/s (98172 kg/h), the calculated air flow is 35.9892 kg/s (129561 kg/h). Obviously, the air flow requirement would change significantly depending upon air temperature, inlet water temperature and flow rate, and other parameters, and that is why cooling towers typically have multiple cells, often including fans that have adjustable speed control.

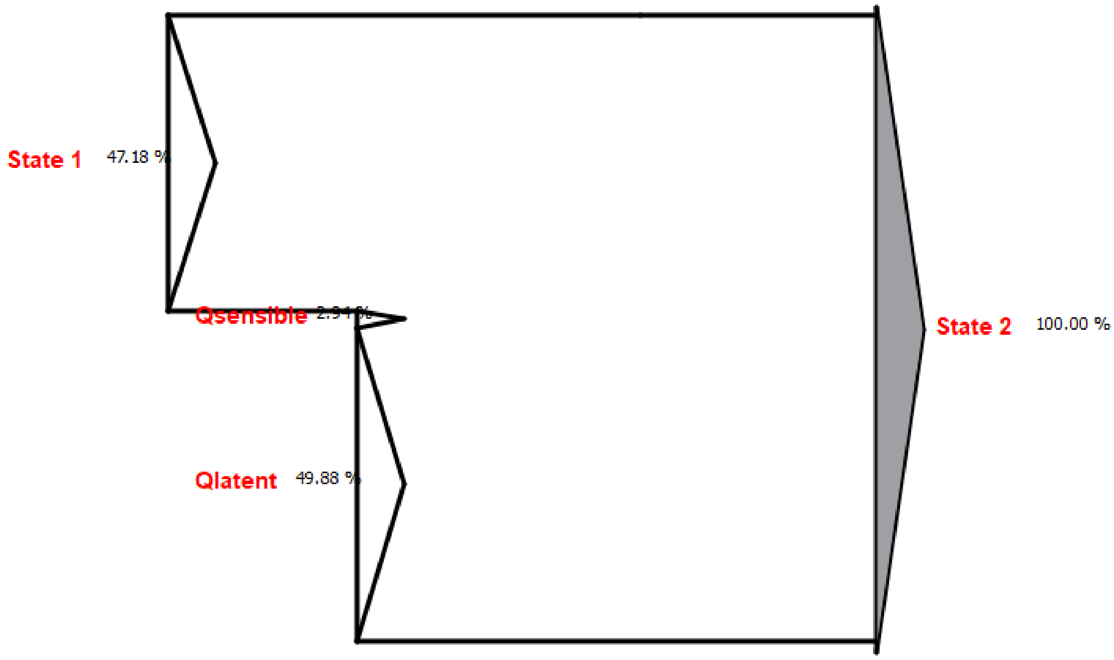
Results	1-2	Units
Delta-w	20.344	g/kg
Delta-RH	64	%
Delta-Tdb	3	°C
Delta-Twb	13.3091	°C
Delta-v	0.0368288	m^3/kg
Delta-h	55.0683	kJ/kg
Delta-s	0.186272	kJ/kg °C
Sensible heat	110.338	KW
Latent heat	1871.53	kW
Total heat	1981.87	kW
Energy efficiency	100	%
Generated entropy	0.0621551	kW/°C
Irreversibility	18.4072	kW
Exergy efficiency	73.4136	%
Makeup water	0.732163	kg/s
Water temperature	30.832	°C
Humidifier efficiency	99.4	%
Bypass factor		%
Apparatus dew-point		°C
Recuperator efficiency		
Percent evaporation	2.63652	%

A very interesting aspect of this calculation is that only about 2 percent evaporation is sufficient to provide so much cooling. For those wishing to more quickly evaluate cooling tower evaporation, a simpler equation is available.

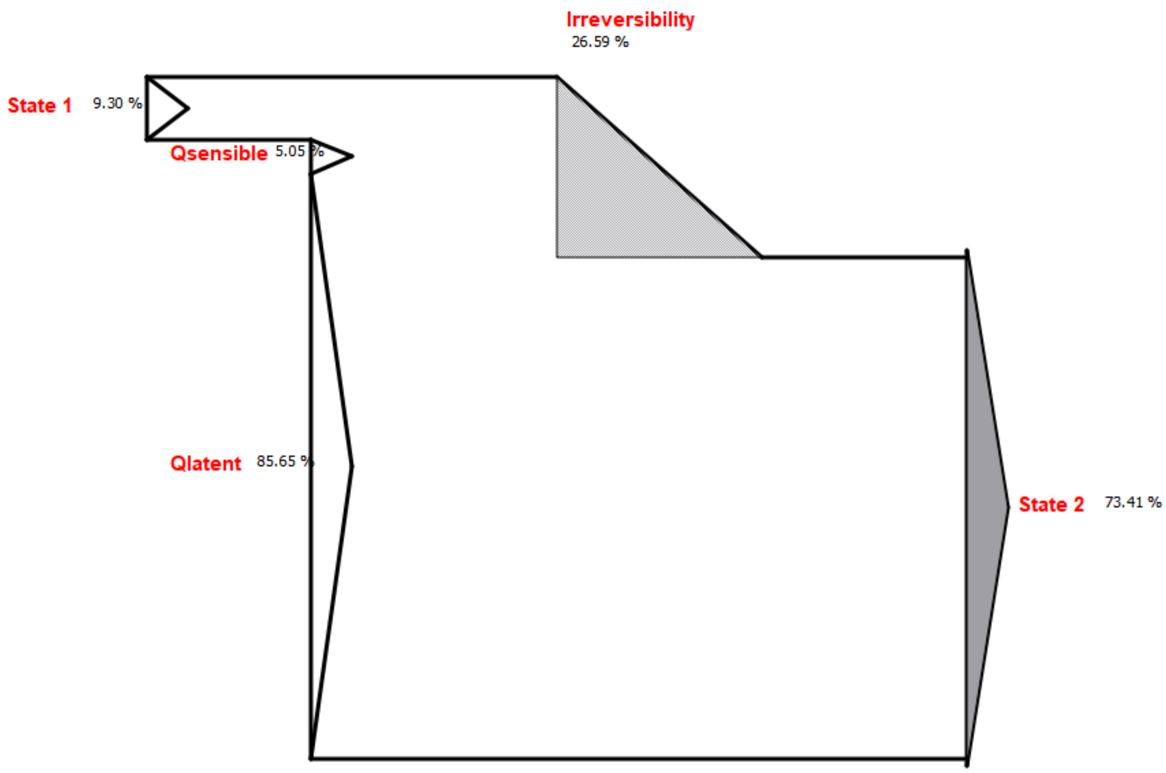
$$Evap(\%) = 100 \cdot (\text{Makeup water}/\text{Water mass flow}) = 2.63652\ \%$$

Variable	State 1	State 2	Units
Pressure	101325	101325	Pa
Dry bulb temperature	28	31	°C
Relative humidity	35	99	%
Humidity at saturation	24.1171	28.8795	g/kg air
Specific humidity	8.23345	28.5774	g/kg air
Degree of saturation	0.341395	0.989541	
Dew temperature	11.1241	30.8207	°C
Wet bulb temperature	17.5511	30.8603	°C
Density	1.15716	1.10986	kg/m^3
Specific volume	0.864182	0.901011	m^3/kg
Saturation pressure	3782.39	4496.16	Pa
Vapor pressure	1323.84	4451.2	Pa
Enthalpy	49.1806	104.249	kJ/kg air
Entropy	0.175983	0.362255	kJ/kg air °C
Air pressure	100001	96873.8	Pa
Total exergy	0.145537	1.14845	kJ/kg air
Thermal exergy	0.0426513	0.112651	kJ/kg air
Mechanical exergy	0	0	kJ/kg air
Chemical exergy	0.102885	1.0358	kJ/kg air
Dry air mass flow	35.9892	35.9892	kg air/s
Volume flow	31.1012	32.4267	m^3/s


PSYCHROMETRIC CHART
SI Units
Sea Level
Dry Bulb Temperature (°C)
Specific Humidity (g/kg air)
Vapor Pressure (kPa)



Energy diagram



Exergy diagram (Grassmann diagram)