# Natural Draft Dry Cooling Tower

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The location of geothermal power plants in central Australia raises the need for a cooling method that is not dependent on large volumes of water. The natural draft dry cooling tower is an alternative to conventional mechanically driven or evaporative systems. This design is being completed for a geothermal plant located in Innamincka, South Australia. The design of the cooling tower incorporates the arrangement of heat exchangers and the tower structure itself. This is dependent on the ambient conditions of the area and the required heat rejection rates.

In a natural draft dry cooling tower air acts as the cooling medium to condense steam that is pumped through heat exchangers. Air is drawn in at the base of the tower and passes through the heat exchangers. This heated air is forced up the tower by the pressure difference created between the warm air and the ambient conditions. The heat exchangers can be placed wither vertically around the perimeter or horizontally within the mouth of the tower. This is a suitable alternative as water is not evaporated to the atmosphere and is reheated to run through the turbine again. The cooling tower will operate most effectively with a larger temperature difference and a greater tower height.

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## Alternative Cooling Methods

This system can be considered as an alternative to mechanically driven systems which incorporate large fans to drive the flow of air through the tower. There is an obvious advantage to this as the flow through the tower can be controlled independently of the temperature difference which increases the reliability of the system to cool. This means the cooling structure can be smaller requiring lower initial investment. The use of fans does require a significant power output of approximately 10-15% of the plant's output. They also require continuous maintenance and generate significant amounts of noise (Forgo 1979).

Another alternative, evaporative cooling is quite similar however water sprays are used as opposed to heat exchangers. This does result in a more efficient system as the latent heat of water removes more heat, resulting again in a smaller tower with a lower initial investment. There is significant water loss which can be up to 3 million litres annually which is not viable for central Australia. The run off created by wet cooling towers creates an environmental hazard due to chemical additives in the water and the wet plumes can be quite corrosive to the tower structure. Hence a natural draft dry cooling tower is most appropriate for the conditions of this power plant.

## Tower Structure

The dimensions of the tower are dictated by the flow requirements for heat rejection at the ambient conditions. The shape and material selection are important to ensure the tower is strong against wind loading, buckling and vibration.

To reject the heat from a 23MW power plant at a 30°C ambient temperature the following dimensions listed in Table 1 are required the location of which are presented in Figure 1.

Table 1: Tower Dimensions

| | | |
|---|---|---|
| Outlet height | 200 m | H5 |
| Inlet height | 16 m | H3 |
| Throat height | 170 m | Ht |
| Throat diameter | 136 m | D5 |
| Inlet diameter | 170 m | D3 |

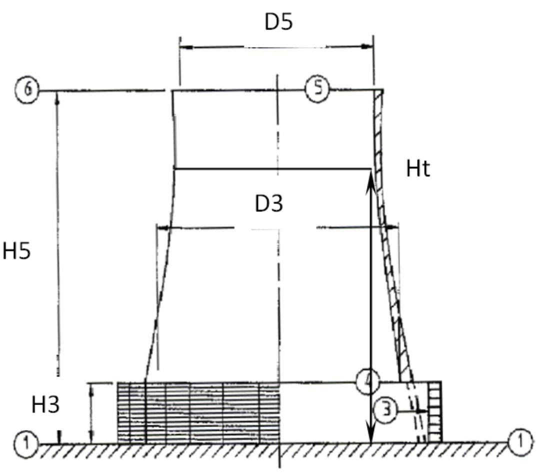


Figure 1: Outline of Tower Dimensions

The tower is hyperbolic up to the throat diameter and then extends straight up. The shell of the tower depends on material selection which is most commonly concrete or steel. This design is slightly different and incorporates a steel frame with square hollow beams that support a material shroud. The selected material covering must be sufficiently strong and stiff to withstand wind loading, durable and resistant to UV degradation.

Wind loading has been applied with a maximum gust speed of 27.8m/s at a height of 10m. Results from a static analysis indicate the maximum deflection would be 2.9m with a stress of 375MPa. Based on this the high strength low alloy steel A582 (grade 65) has been selected. This has a yield strength of 450MPa which is sufficient for the loading conditions. A possible frame design has been modelled and loaded in Strand7 and is presented in Figure 2.

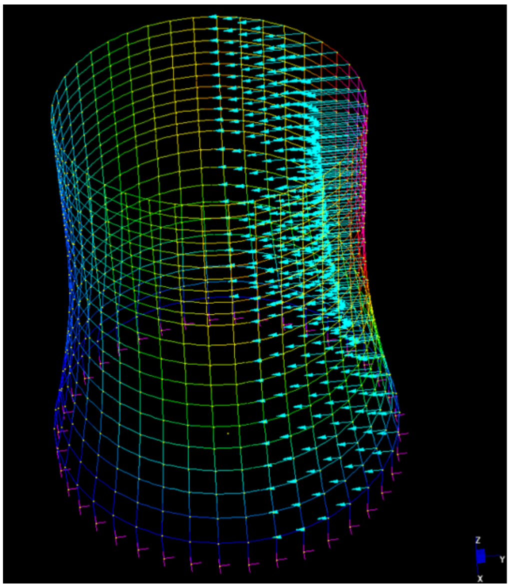

Figure 1: Strand7 model of a cooling tower under wind loading

There are advantages to a steel frame over a concrete shell. As there is a low possibility of seismic shocks due to the creation of fractured rocks underground the the shell must be strong against cracking. Steel is more likely to withstand ground vibrations without failure. Steel is also suitable as this is a dry tower so corrosion is not a major issue.

## Heat Exchanger Design

The design of the heat exchangers requires the selection of the heat exchanger location as well as the design of the finned tubes within the bundles. The heat exchanger arrangement must be designed to minimise the pressure drop in air flow while maximising the heat transfer.

The bundles can be located either vertically around the circumference of the tower or horizontally within the mouth of the tower. Some of the common arrangements are presented in Figure 3. The difference in thermal performance between the various arrangements is quite minimal when considering one dimensional flow through the tower. It is only when considering the effect of wind flow around the tower that the difference in performance is observed (Moore 1978).

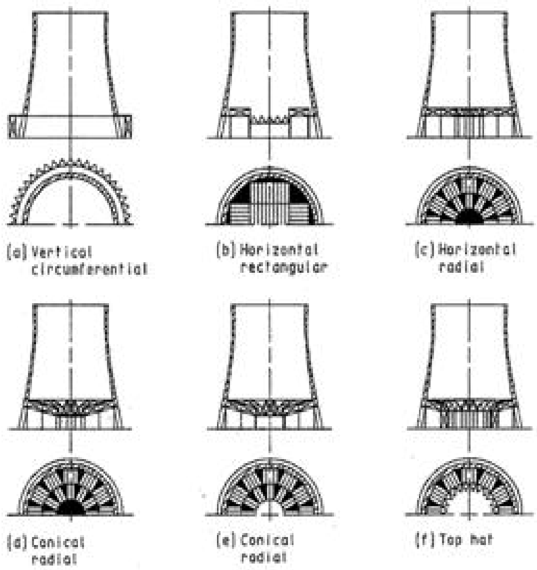


Figure 3: Common Heat Exchanger Arrangements (Kröger 2004)

For this tower design a vertical arrangement has been chosen as the bundles are self supported and arrangement is simple to model. The flow losses through the heat exchangers can be calculated analytically to determine the resistance to the air flow. A draft equation has been proposed by Kröger which equates the flow resistances to the pressure drop as the height increases.

$$\Delta P_a = (\rho_{a1} - \rho_{a5}) g \left[ H_5 - \frac{H_3 + H_4}{2} \right] = \sum Flow\ Resistances$$

Equations for the resistances have been proposed and have been calculated iteratively to determine the mass flow rate through the tower and determine the size of the bundles.

Heat Exchanger specifications for this tower are listed in Table 2.

Table 2: Heat Exchanger Specifications

| | |
|---|---|
| Number of Bundles | 196 |
| Total Number of Tubes per Bundle | 1350 |
| Rows of Tubes | 9 |
| Length of Tubes | 15.6m |
| Number of Water Passes | 2 |
| Outside Diameter of Tube | 40mm |
| Outside Diameter of Fin | 80mm |
| Number of Fins per metre | 60/m |

The bundles are arranged vertically around the circumference of the tower at an angle of 60° to the tower. These results have been compared to the AspenTech Heat exchanger design program to ensure that the surface area of the finned tubes is sufficient.

## Performance Analysis

The performance of the natural draft dry cooling tower is quite dependent on the weather conditions. As the ambient temperature increases the cooling capacity and the performance of the power plant decreases which is the primary concern in the use of natural convection. As the ambient temperatures will peak in the summer months when the power usage is often at its greatest, this requires some investigation to determine the viability of this method. There will also be significant temperature drop during the night so there will be some variation in the performance of the tower over a daily and monthly time frame.

Wind acting around the tower will also affect the cooling performance. The direction of air entering the tower changes due to the effect of wind as is evident in Figure 4. Ideally, air enters perpendicularly to the face of the heat exchanger to minimise the pressure drop in the flow. An investigation conducted by Moore (1978) to determine the effect of varying the angle found that for angles greater than 75° (from perpendicular) the flow is negligible. The use of wind break walls is proposed by Du Preez (et.al. 1995) and seems to minimise the effect of the wind.

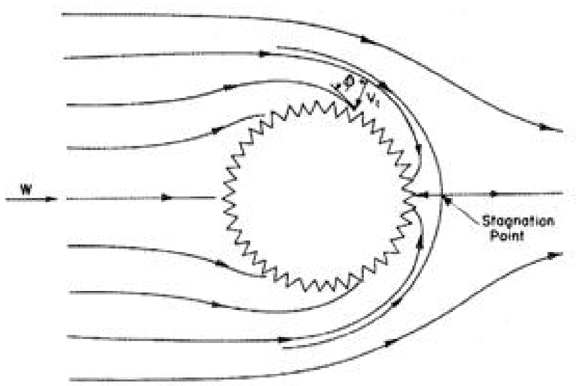


Figure 4: Possible wind streamlines (Moore 1978)

## Summary

The natural draft dry cooling tower would provide an alternative cooling method when large quantities of water are not available. Investigation is required to determine whether it is suitable for a power plant in South Australia based on the ambient conditions of the location. A tower of 200m is required to cool the 23MW power plant in 30°C ambient conditions. Vertical heat exchangers are arranged around the circumference to allow for heat transfer.

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