OPTIMUM SELECTION OF COOLING TOWER

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ABSTRACT : The selection of cooling tower is influenced by a number of factors. Proper selection of cooling tower can bring the best performance out of it. A faulty selection may prove to be detrimental to the plant. The present article deals with a thorough literature survey regarding the comparative study and, therefore, the selection of cooling towers. The performance of a cooling tower is highly case-dependent and one has to be very careful a while choosing the best cooling tower for given industrial application.

1. INTRODUCTION

A cooling tower is an enclosed device for evaporative cooling of water by contact with air. Industries use cooling water in various processes. As a result, there are also various types of cooling towers. There are cooling towers that create process water that can only be used once, before it is discharged. There are also cooling towers that create water that can be reintroduced in the production process. When water is reused, it is pumped through the installation into the cooling tower. After the water is cooled, it is reintroduced into the production process.

Cooling towers play a vital role in many industries, especially in industries where large quantity of waste heat is rejected, such as power stations and air conditioning industries.

2. MAJOR INFLUENCING FACTORS

2.1 Ambient conditions

In case of Natural Draft towers wet bulb temperature and relative humidity both are very important parameters. In case of Induced Draft towers wet bulb temperature is the parameter to consider. For stations operating on cooling towers, the normal design cold water temperature is in the range about 30-33 °C. Usually the design ambient conditions for the cooling tower are selected such that these are not exceeded 95% of the time during summer months i.e. May, June, July and August. These months have high wet bulb temperature which represents the most severe operating condition for the tower. High wet bulb temperature (about 30 °C) and moderate relative humidity conditions are more severe for Natural Draft towers and during these conditions for a few hours in a year Induced Draft towers performs better than Natural Draft towers. The load factor is assumed to refer exclusively to that proportion of the year over which the tower operates at full load.

Apart from this, with a mean temperature of

40^0F there is no economic application at all for the mechanically ventilated towers, however low the exhaust heat loading. Canada or Northern European countries are examples of places where Natural Draft towers will consequently tend to predominate. It has been found that with mean temperature of 70^0F or over, Natural Draft towers are not suitable. Countries where such temperatures are habitual may require mechanical equipment. Britain has average temperatures about 10 ^{0} lower than the USA, and, perhaps, this is the reason for the preference for Natural Draft cooling in the former country for serving electrical power stations.

2.2 Capital cost

Natural Draft towers have a higher capital investment, typically about 66 to 70% higher than Induced Draft towers. This amount of additional cost results in higher interest, depreciation charges etc. during the life times of the plant which must be taken into account while selecting a cooling tower. Again if soil conditions at a particular site requires a costlier foundation design it will, in turn, affect the overall cost comparison between the towers.

2.3 Fuel cost

Actually, increase in fuel cost has a far-reaching effect in the sense that it will, in turn, increase the cost of generation and ultimately the cost of auxiliary power increases. Hence in the cases where cost of generation is high Induced Draft towers suffer in comparison to Natural Draft towers due to fan power consumption by the former types. It may be noted that while evaluating auxiliary power cost only marginal fuel cost has been taken into account at part loads.

Again, the performance of Induced Draft towers and Natural Draft towers are different over the years even though they may have been designed to give the same cold water temperature at the design point. The re-cooled water temperature for the tower will vary over the year and hence affecting the turbine performance. Fuel cost which affects the evaluation of the turbine performance has also to be accounted for.

2.4 Operation and Maintenance

In case of Induced Draft towers the operation and maintenance cost for the running equipment, e.g. fans, motors, gear boxes etc. and the spares required for the same will have to be considered in selection of the type of the tower. Besides that, replacement of the rotating equipment of Induced Draft towers may be necessary during the plant life which has not been covered in this article.

2.5 Type of fill

Most of the cooling towers in the world have been built with wooden fill. Since India has a very little wood for industrial purpose available, concrete beams have been used. The heat transfer capacity of this material is very poor and demands very large cooling towers for a given thermal duty. In India most of the power stations use splash type fill. However, recently for some of the stations such as Auraiya combined cycle project and National Capital, Regional Thermal Power Plant (NCTPP) at Dadri, film type fill has been selected. Film type fill can be used when the circulating water quality is closely controlled. These have been used by NTPC stations where filtered and softer water is used. The typical fill height in film type cooling tower is about 1-1.5m as compared to about 6m for splash type counter flow tower. This results in enormous savings in CW pumping power which must be considered in evaluating the type of fills and hence the type of tower.

Heat transfer surface is not always equivalent to heat transfer capacity. There are film type products by $333 m^2/m^3$ available of which thermal efficiency is smaller than of a honeycomb material with only $138 m^2/m^3$ (Schultz). This shows that it is important how the shape of the fill material is designed. In this respect it is necessary that the surface of water film is turbulent and the water quality on the surface is sufficient to form a water film.

Any manufacturer of cooling tower fill generally does not have the knowledge to optimize cooling systems because for this purpose he needs all relevant information starting from the boiler, the minimum steam temperature in the low pressure of the condenser. Nevertheless, in USA and also in Europe it has been proved that a reduction of investment cost by 20% of the total cooling tower cost is possible by using high efficient fill media.

One astonishing fact is that even a specifically high pressure drop ends up with lower fan power demand. Actually, the quantity of air is considerably reduced in connection with the high transfer capacity of the fill.

2.6 The effect of the turbine exhaust heat loading upon the economic water temperature

With bigger turbines the exhaust area is insufficient to cope with the quantity of heat rejected, so that the turbine exhaust heat loadings increase and higher water temperatures become economic resulting in less exacting cooling tower duties. For given duty conditions, the economic water temperatures are lower for Mechanical draft than for Natural Draft towers. It would appear that low temperature ranges are not generally economic. Cost factors for condensers are more variable than those for cooling towers and may influence the cost of the power station buildings. Representative figures have been chosen for preparing the broken line curves. High exhaust heat loading is advantageous to Natural Draft towers. The increases in turbine exhaust heat loads produce increases in economic water temperatures, which in turn induce a reduction in the economic ground area of the chimney. The same air power can therefore be developed for less capital cost.

2.7 Input Data and Economic Methodology

There is some input data listed in the Annexure-1 as given by Mr. R. K. Narayan in his paper on cooling tower selection. The salient input data are discussed further below :

A study has been carried out for a typical 710 MW (thermal) unit with an assumption that each unit will be catered by one tower. The cooling tower parameters are based on NCTPP at Dadri. The capital cost data for the towers are based on recent contracts awarded by NTPC, duly modified to account for escalation and site specific conditions. Other performance actors such as differential pumping head requirements and fan power requirements have been based on the performance data bank available for cooling towers with NTPC.

It has been found that though Induced Draft towers had a lower construction period and consequently less interest liability during construction period as compared to Natural Draft towers, the escalation in capita cost till the order date compensate for the higher interest. Hence based on a detailed fund low analysis the escalation and IDC factors for both types of towers are given in Annexure-1.

The fixed charges applicable on capital investment such as interest on loan capital, return on equity capital and depreciation charges, works out to 15.1%, the operating and maintenance charges have been assumed a 0.25% of he installation cost for Natural Draft tower and 2% o the installation cost for Induced Draft tower and have been leveled to account for escalation over the plant life.

Based on recent cost estimates for thermal projects the fixed cost portion of the cost of generation has been taken as 0.50 Rs/kW.hr at 60% PLF. The running cost portion which is inked to the coal cost has been varied for a wide range of coal cost from Rs. 200/- tonne to Rs800/tonne as delivered at project.

Another important consideration is that though a generating unit operates at different load levels, resulting in a PLF say 60%, the CW pump and cooling tower operating hours should be based on the number of hours he generating unit is available. Based on the above consideration the number of hours of CW system operation have been assumed equivalent to the unit availability hours.

Over the past three decades the fuel price has been escalating at a compound rate of about 10%. The study assumes a base fuel escalation rate as 1% and sensibility analysis has been carried out for 0 to 15% variation in coal price escalation rate.

For most of the power stations in the country, reliable meteorological data is not available. To the subject study, near to the power station site, the Hindon air force base has detailed three hourly meteorological data recorded for a period of more than five years.

Based on the annual fire charge rate applicable, the annual cost of the capital investment is evaluated. Based on the performance parameters, the annual operating cost for both auxiliary power consumption and turbine performance is evaluated. The total evaluated cost has been arrived at as the sum of the present worth values of the annual cost of the capital and annual operating cost. The present worth evaluation is inherently consistent and is widely used world wide for techno-economic studies for power utilities.

3. GENERAL FINDINGS

1. Any kind of techno-economic study conducted for selection of type cooling tower requires an evaluation of the year round performance of the tower. The Natural Draft tower performs more efficiently for 95% of the time in a year a compared to Induced Draft tower when both the towers are designed for the same summer ambient conditions.
2. For station with a high fuel price, say for load centre based stations with high transportation cost, the Natural Draft tower is the optimum choice. This holds good irrespective of the PLF and fuel price escalation rate applicable for the project.
3. For pit head stations operating on base load, Natural Draft tower is the economic choice when fuel escalation rates are above 10%. With lower fuel escalation rates, Induced Draft tower can be considered to be more economical for pit head stations.
4. For pit head stations operating as post load stations, Induced Draft tower is the optimum choice. For escalation rate of around 10%. Though for these stations also at 15% coal escalation rate, Natural Draft tower can be considered as more economical.
5. From all these points, it can be said that for utility applications with medium to large sizes, Natural Draft tower may be the optimum choice.

This will be more so when the Indian industry acquires the capability of building one tower for a large capacity unit such as say 500 MW and above.

But there are several other factors which may govern the selection of type of cooling tower. For example:

- Geological condition of the site.
- Climatic conditions such as temperature (dry bulb and wet bulb), relative humidity.
- Elevation of the site. For example in case of hilly areas the effect of pressure may be an important consideration.
- Wind effect.
- Quality control, planning, scheduling etc.
- Proper construction technique.

ACKNOWLEDGEMENT : The author is indebted to all members of the Data Centre, M/S Development Consultants Pvt. Ltd., Kolkata, for their kind and active cooperation and help.

4. REFERENCE

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[2] Narayan R.K., "Optimum Selection of Type of Tower for Power Stations", National Seminar on Cooling Towers, 18-20 Jan, 1990

[3] Schultz Martin, "PVC Fill Media for Use in Cooling Towers", National Seminar on Cooling Towers, 18-20 Jan, 1990

ANNEXURE - I

INPUT DATA :

TECHINICAL INFORMATION :

A) Design conditions :

a) Flow rate : 25,000 m^3/hr
b) Range : 11 °C
c) Approach : 5 °C
d) Wet Bulb Temperature : 27 °C (considering recirculation allowance)
e) Relative Humidity : 50%

B) Pumping Head requirement in MWC at ground level and corresponding Pumping Power in kW :

Type of Tower	Pumping Head, MWC	Pumping Power, kW
Natural Draft Splash	14	1176
Natural Draft Film	10	840
Induced Draft Splash	13	1092
Induced Draft Film	9	756

C) Cooling tower Fan Power requirement :

Type of Tower	Fan Power, kW
Induced Draft Splash	635
Induced Draft Film	550

D) The difference in cost of CW Pump Motor due to difference in CW Pump Head has also been taken into consideration in this study.

a) Cooling tower cost is on date :

Type of Tower	Cost (Rs., lacs)
Natural Draft Splash	520
Natural Draft Film	570
Induced Draft Splash	320
Induced Draft Film	350

b) Escalation and IDC factor
Escalation rate 8%
Interest rate 12% = 1.27

c) Leveled annual fixed charge rate for

Type of Tower	Rate, %
Natural Draft	16.6
Induced Draft	20

Break up of fixed charges interested on loan capital = 15%

Return on equity capital = 10%
Depreciation = 3.6%

Base Operation and Maintenance charges Natural Draft Tower 0.25% of installed cost.

Type of Tower	% of Installed Cost
Natural Draft	0.25
Induced Draft	2

Loan capital equity : Equity capital = 1:1

d) Fixed Cost part of cost of generation

% Load	Amount in Rs./kWh
30% PLF	1.16
50% PLF	0.70
60% PLF	0.58
70% PLF	0.50

e) Variable Cost part of cost of generation is linked with base coal price and escalation rate and has been duly considered in this article.