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An Approach for Water Cost of Cooling Water System in Oil Refinery

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Nowadays water and energy are two main requirements of oil, gas, petrochemical and chemical processes. After the energy crisis in the seventies decades minimization of energy consumption become a major problem for industries, water was considered the most important source of industries requirement, after energy. This article reviews the cases of water and energy losses in cooling towers of oil refineries. Cooling towers are the equipment to set the temperature cooling water service of integrated oil, gas and petrochemical used. Hence, the significant transfer of air and water to create moist air from the process cycle casualties is removed. The main goal of this research is to reduce water cost of cooling water system of the oil refinery. Economic principles in order to review the definition of an objective function for a Trade-off between construction cost, installation and operation dry cooling tower and reduce the cost of wet cooling tower make-up water is more. Results obtained from studies in the sample case study objective function, the Tabriz refinery cooling towers were selected, expresses that: There is no economic justification for replacement method, also saving cost in series hybrid method is 171,600 $/y and in split method is 212,400 $/y. Presenting the proposed method based on dry bubble temperature variations during the year can be a combination of two methods used to determine the best route in the cold months of the year (December, January and February) split method and the rest months use series method to the cost saving result is expressed 281,100 $/y.

1. Introduction

Industrial processes use a lot of water for cooling purposes. Cooling water is used to extract unusable heat from process streams. The hot water from on ‘once through cooling’ system cannot always be discharged into lake, river, canal, etc. Discharge of hot water causes thermal pollution and can severely affect the aquatic creatures and algae in natural water. Only a small quantity of makeup water is necessary to compensate for the losses during use. The losses are mainly due to evaporative cooling. Cooling of warm water is done by direct contact with air in cooling towers. Water is fed at the top of a cooling tower and air is drawn at the bottom or through the side walls.

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Evaporative with air cooling of water occurs in the tower, the latent heat of vaporization being supplied mostly by the water itself.
To solve the problem of makeup water cost of waste water in cooling towers, dry cooling towers are used instead of wet cooling towers. Dry cooling towers are the equipments where the water flows in pipes by having the blade, had no direct contact with air. This paper investigates the economic alternative dry cooling tower in some parts of the year. Different methods are studied for reducing the cost of makeup water by hybrid cooling system vs. dry cooling system. In this research, Tabriz oil refinery cooling system is used as a case study.

2. Cooling Tower

The cooling towers are the equipments which cooling operation involves 'simultaneous transfer of heat and mass. Two types of temperature the 'dry-bulb' and the 'wet-bulb' temperature are defined in connection with air-water contacting. Considering the fact that in dry cooling towers circulatory cooling water temperature lower than the temperature of the bubble is not possible; with recognizing losses in water systems, cooling tower replacement conditions dry instead of wet cooling tower more general, or at least part of the year will examine. Economical method to determine the replacement cost, which includes replacement (the cost of construction, installation and commissioning of dry cooling tower, pumps and related pump and fan electricity costs) cost of water is decreased due to compensatory replacement of whole or part year and compared in terms of replacement cost less than compensatory cost savings by water, the alternative methods will used. The summation total of waste waters called 'Makeup Water'.
Economic principles in order to review the definition of an objective function for a Trade-off between construction cost, installation and operation dry cooling tower and reduce the cost of wet cooling tower make-up water is more.

Objective Function = (Makeup Water Cost) **-** *[(Dry Cooling tower Cost) + (Pump Cost) + (Fan Cost)* (1)

In the replacement study of dry cooling tower instead of wet cooling tower, the most important factor is determining the area needed for a certain amount of water in the dry cooling tower. By determining the required area and calculate the overall cost of the dry cooling tower in comparison with the makeup water level decreased due to compensatory hybridization can be economical in the project be evaluated and discussed.
The equations and formulas which required calculating above function for economic comparison of wet cooling tower instead of dry one are illustrated in references.

3. Case Study

In this paper, the cooling water system of Tabriz refinery is used as a case study. For this purpose data collected from weather Meteorological Organization and process cooling water system of the refinery in a one-year period were collected. Methods In this paper, study the conditions of dry cooling tower replacement instead of wet rather than a general or conditions and different scenarios, with analysis advantages and disadvantages of each mode and compare the technical and economic methods to achieve an optimal state of proposed economic and will.

3.1 Number of Days Allowed Replacement of Dry Cooling Tower Instead of Wet

At first, the highest monthly mean air temperature charts of Tabriz vs. months of the year to be draw. Now consider approach temperature equal to 3 °C then moving the size of chart before 3 °C to achieve a minimum water temperature output from the tower in the average monthly temperatures reach. Based on data of Tabriz Refinery output water temperature required by the cooling tower is 28 °C. Now if we draw a line under temperature 28 °C months in parallel to the axis. In this case in the days since that low place crosses the line and put the chart are alone dry cooling tower can be used. Number these days is about 245 days.

According to the data of the Tabriz oil refinery; current cooling tower makeup water volume is 762.5 (m^3/h), which is injected to the system in two parts:

1- Raw makeup water rate of approx. 11% of the total makeup water price 0.086 \$/m^3

2-Treated makeup water rate of approx. 89% of the total makeup water price 0.154 \$/m^3

Thus the cost of monthly makeup water of Tabriz oil refinery is 80,400 \$/month.

3.2 Dry Cooling Tower Design Calculations

Using design following information and assumptions will use:

Average circulating water temperature 49°C, environment air temperature (dry bubble) 23.3°C, refineries altitude of main sea level is 1362 m. forced draft dry cooling tower with two fan and fin pipe with 25.4 mm outer diameter, 15.9 mm blade height, BWG=12, 64 mm tube pitch, Triangular pipe design bundle, 18.28 m pipe length, 4 row tube and 7 pass tube, carbon steel pipe material, extruded aluminum fin material (0.4 fin number/mm)

Calculating the real power pumps and electric power fan motor monthly electricity costs can be equal to Power 25.2 \$/month can be calculated. Cooling tower operates in all hours of day and night in rest of the year so cooling system operating time is equal to 720 h/month.

3.3 Study on Replacing Dry Cooling Tower Instead of Wet in 67% Days of a Year

In this study, according to the presented objective function there is an economical balance between decreasing makeup water cost of current wet cooling tower and increasing installation cost of dry cooling tower with attentive to explained methods in compare with decreasing makeup water cost. Replacement method for dry cooling tower instead of wet in 245 days of year is suitable and economical. In table 1 operation parameters and estimate of dry cooling tower installed cost has been shown.

Table 1: Dry Cooling Tower Cost in Replacing Method in Terms of \$/month

Temperature Range (°C)	28
Heat capacity of dry cooling tower (Q MW)	373.34
Required area for heat transfer (m^2)	61,300
Motor shaft power of fan in Temp. range (kW)	6,360
Construction, installation and commissioning cost (\$)	1,310,000
Dry cooling tower cost (\$/month)	2,095,000

Table 2: Total Replacing Cost Comparison with Saved Makeup Water Cost ($/month)

Description	Quantity
Dry cooling tower cost ($/month)	2,095,000
Fan electrical cost ($/8 month)	1,309,000
Pump electrical cost ($/8 month)	86,800
Pump cost ($/8 month)	82,100
Total replacing cost ($/8 month)	3,573,000
Wet cooling tower water cost ($/8 month)	643,200

By comparing the total replacement cost of dry cooling tower by annual makeup cost we find this method is not economically efficient (Table 2). However the described problems related to the cooling system to review hybridization method in this system.

3.4 Hybridization of Tabriz Refinery's Cooling System

There is tow suggestion method for current wet cooling tower hybridization:

3.4.1 Series Method of Current Wet Cooling Tower with a Dry Cooling Tower

In this method, firstly the rest of returned process hot water entered to dry cooling tower and cold water to determine temperature. Then this water entered second stage to the wet cooling tower to reach the required temperature.

3.4.2 Split Method of Current Wet Cooling Tower with a Dry Cooling Tower

In this method, hot water entered to dry cooling tower and the rest of the water sent to wet cooling tower. The water which a few degrees drop in temperature then sent to dry cooling tower to reaches required temperature. Splint method in two directions is achieved (Figure 1).

Split method, Path A

In this path, the amount of water which lost its temperature in dry cooling tower will be mix with the remaining water which has not yet miss temperature before entering to wet cooling tower then all amount of water entering to wet cooling tower.

Split method, Path B

In this path, the exiting water from dry cooling tower is directly strewing wet cooling tower to achieve to refinery required temperature.

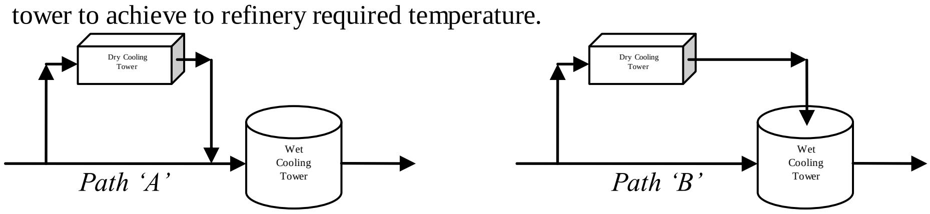

Figure 1: Global Aspect of Split Method of Hybridization System

By Evaluating amount of decreasing makeup water in tow paths 'A' and 'B' and comparing this two quantity conclude that the amount of makeup water in this two paths are equal, So by economical construction reasons path 'B' is chosen.

3.5 Hybridization Method Cost of Series Wet and Dry Cooling Towers

In this study, construction, installation and commissioning cost of dry cooling tower in constant volumetric flow rate 11,500 m^3/h at the different temperature ranges of 4, 6, 8, 10, 12, 14 °C are calculated. Table 3 represent the cost of dry cooling tower, total hybridization cost and makeup water in series method.

Table 3: Fan & Motor Power, Makeup & Hybridization of Dry Cooling Tower Costs in Series Method ($/month)

Temperature Range (°C)	4	6	8	10	12	14
Fan cost ($/month)	17,000	25,000	34,000	43,000	51,000	60,000
Pump cost ($/month)	9,500	9,600	9,700	9,800	9,900	10,000
Total hybr. cost in series method	58,100	78,100	99,300	120,7000	140,800	162,000
Dry cooling tower cost	24,400	36,300	48,400	60,700	72,700	84,800
New makeup water vol. (m^3)	378.0	382.6	386.5	390.4	394.0	397.0
New makeup water volume	69	63.4	58.1	52.5	46.9	41.3

Also by using previous equations, Construction, installation and commissioning cost of pump in series method is 7,200 $/month.

3.6 The Best Condition in Split Hybridization in 32.3°C Dry Bulb Temperature

If 7,134 m^3/h of water cooled by dry cooling tower, from 56°C to 46°C, the amount of annual saved cost for Tabriz refineries cooling system is 17,700 $/month or equivalent to 212,400 $/y.

3.7 Proposed Method

In this method, can determined water flow directions by using valves with proposed of 3 systems; wet, dry and hybrid (series and split) systems in different month of years and for dry bulb temperature of 4, 18 and 31°C Outline of the method in Figure 2 is shown.

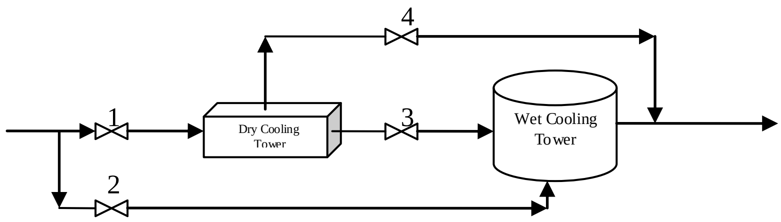

Figure 2: Global Aspect of Split Method of Hybridization System

The circumstances of changing proposed method to dry, wet and hybrid systems is:
Wet systems: valve number 2 is opened and the other valves are closed.
Dry systems: valve number 1 and 4 are opened and the other valves are closed.
Hybrid system:
Series method: valves number 1 and 3 are opened and the other valves are closed.
Split method: valves number 1, 2 and 3 are opened and valve number 4 is closed. In the proposed method to determine the optimal mode in the proposed system, based on months in dry bubble temperature in Tabriz (air temperature and environment) are divided into three categories: Cold months (Dec., Jan., Feb.), Moderate months (March, April, May, Sep., Oct. and Nov.) and Warm months (June, July, Aug.)

4. Conclusion

In Table 4 saved cost of all kinds of hybridization methods in different dry bulb temperature are compared.

Table 4: Saved Cost of all Kinds of Hybridization Method in Different Dry Bulb Temp. Comparison

Method	Season (x Months)	Dry Bulb Temperature °C	Saved Cost ($/x Months)	Total Annual Saved Cost ($/y)
Series	-	32.3	-	171,600
Split	-	32.3	-	212,400
	3 Cold Months	4, 18, 31	77,700	
Proposed (Series)	6 Moderate Months	4, 18, 31	142,800	272,700
	3 Warm Months	4, 18, 31	52,200	
	3 Cold Months	4, 18, 31	86,100	
Proposed (Split)	6 Moderate Months	4, 18, 31	133,200	268,500
	3 Warm Months	4,18,31	49,200	

4.1 Determining the Best Conditions for Hybridization of Cooling Water System of Tabriz Refinery

According to table 4 the condition is optimized which have the most saved cost for cooling system. With comparing table quantity economical way is as following:

1- In 3 warm months with average 31°C dry bulb temperature:
Using proposed system and split method if we cool 4,334 m^3/hr of warm water in dry cooling tower amount of 24°C, the saved cost of three 3 months is equal to 52,200 $.

2- In 6 moderate months with average 18°C dry bulb temperature:
With the proposed system and series method if total warm water is cooled in dry cooling tower amount of 7.7°C, saved cost of the 6 months is equal to 142,800 $.

3- In 3 cold months with average 4°C dry bulb temperature:
Using proposed system and series method if we cool the warm water amount of 6°C by cooling tower, save cost in this 3 months is equal to 86,100 $.

Therefore; total annual saved cost is equal to 281,100 $.

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