Evaluation of Fill Pack Damage to the Cooling Effectiveness of Counter Flow Type Cooling Tower in the Oil and Gas Industry

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Abstract— **In the oil and gas industry, cooling water is needed to cool various kinds of heat-generating equipment and as a backup water requirement. Cooling water in the industry is usually produced by cooling towers in large quantities. The working principle of the cooling tower by exchanging heat from the hot water of a process with exhaled cold air. There is a cooling tower part called a fill pack and has an important function as a place for heat exchange between water and air. In this research in the oil and gas industry, the cooling tower used is a wet cooling tower type with counter flow flow. The purpose of this study is to determine the current cooling effectiveness of the cooling tower compared to its design data. Calculating the effectiveness of cooling certainly requires water temperature data produced by the cooling tower. The method used in this research is the method of taking water temperature data before and after leaving the cooling tower. The level of cooling effectiveness in the cooling tower will be better if the water temperature produced is cooler than the water temperature when entering the cooling tower.**

Keywords— cooling effectiveness, cooling tower, cooling water, fill pack, temperature

I. Introduction

This research was conducted when replacing the fill pack in order to find out the water temperature data before and after repair. Water temperature data is used to calculate the effectiveness of cooling in the cooling tower. The replacement of the fill pack in the cooling tower aims to cool the water to the maximum which is done for 2 to 3 times in 10 years. This is due to the condition of the fill pack which is mossy, dirty, and torn due to continuous hot water. Fill pack is the most important part of the cooling tower because it is a place for heat transfer between water and air [1]. This research was conducted on one cooling tower, so as not to interfere with the performance of other cooling towers. Water temperature data collection is carried out in the Distributed Control System (DCS) room. Water temperature data taken is 7 days before fill pack replacement and 7 days after fill pack replacement. Fill pack replacement itself is carried out for 10 days, so it takes 24 days to get water temperature data.

Cooling water in the oil and gas industry is needed to cool the equipment used after going through a process. The cooling effect of cooling water is very beneficial for the equipment because it can help to neutralize the temperature and not damage the equipment and can extend the life of the equipment. In general, cooling water is flowed through pipes on equipment that can generate heat and requires cooling. Initially, cooling towers were used to save costs and as an effort to reduce the use of clean water for cooling water [2]. Cooling tower works by contacting water with cooling air and then some of the water will evaporate [3]. Some of the water that evaporates during the process of cooling the equipment will be replaced by adding water to the cooling tower (make up water) [4]. Examples of the use of cooling water such as generators, boilers, condensers, and other equipment.

In the oil and gas industry with large production processes usually use cooling towers to produce cooling water. Cooling tower is a cooling tower that is used as a heat exchanger using a working fluid in the form of water as a heater and air as a coolant so that the cooling tower becomes a more effective water cooling system than others [5]. The cooling tower used has a counter flow type, which means that the water and air move in opposite directions [6]. Most of the cooling towers use pumps to move water vertically upwards across the tower. All cooling towers in the industry work by releasing heat from hot water from a process that is pumped into the cooling tower. The air will be forced by the fan so that it passes through the fill pack and collides with the water [7]. Broadly speaking, the cooling tower has a function as a heat sink from pumped water and produces cooling water for a process [8]. There are also water evaporation losses in the cooling tower due to incoming air [9]. However, this study did not calculate it because it did not look for water circulation rates.

II. Methods

The working principle of the cooling tower by releasing heat and can transfer heat from a moving fluid to another fluid, so that the cooling tower can reduce the temperature of hot water with the help of blowing air. Some of the water that collides with the air during the heat transfer process will evaporate with the air so that the remaining water will go down to the bottom with a cold temperature. Air and water vapor will escape to the top of the cooling tower either naturally or with the help of a fan. The cooled water will go down to the bottom and reach the basin (cold water reservoir before reuse). Cooling tower works for 24 hours and never stops because the results of cooling water are always needed for any heat-generating equipment. Generally, the number of cooling towers in the industry is not just one, so that if there is damage to one cooling tower, then the others can still work to produce cooling water.

Cooling in the cooling tower occurs because there is evaporation of some of the water into the air flow and the

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water molecules carried by the air will be partially captured by the drift eliminators. The air mass or vapor coming out of the cooling tower will be more humid and heavy because there are water molecules that are carried away. If there is water carried by the air, the volume of water will decrease little by little along with the cooling process in the cooling tower. Therefore, there is a make up water valve pipe that will increase the volume of water so that the cooling process runs smoothly and the volume of water is fulfilled.

In the cooling tower there are two types according to the flow of air and water, namely counter flow and cross flow. This counter flow type cooling tower has an air flow direction that blows upwards and in the opposite direction to the water flow that is dropped down. This type of counter flow has a higher cooling effectiveness compared to the cross flow type. In this cross flow cooling tower type has the direction of the air flow that blows horizontally and cuts the flow of water dropped down. This type of cross flow is easier to clean because it is easier to enter the inside. This research uses the counter flow cooling tower type because it has a higher cooling effectiveness.

This study was conducted to determine the effectiveness of cooling contained in the cooling tower. In the oil and gas industry, it can produce up to 33,400 tons per hour of cooling water in one cooling tower [10]. The type of cooling tower here is a wet cooling tower with counter flow. There are 10 cooling towers of the same type in one unit, while in another unit there are 6 cooling towers of the 149.9 m^2/m^3 same type.

The following are the design data of the cooling tower with counter flow, including:

Table 1. Cooling Tower Design Data

General	
Type	Counter flow
Design & Operating Conditions	
Circulating Water Flow	33,400 tons/hr
Hot Inlet Water Temperature	45.5ºC
Cold Outlet Water Temperature	33ºC
Wet Bulb Temperature	29.1ºC
Drift Loss	0.003 %
Evaporation Loss	1.97 %
Design Wind Load	125 Km/hr
Basin Water Retention	10 minutes

In this study, the replacement of fill packs is carried out routinely 3 times every 10 years. Some of the things that affect fill pack damage and are considered to be replaced are:

a) The durability of fill packs that begin to decrease due to continuous passage of hot water.
b) Brittle of torn due to age and continuous passage of hot water.
c) The emergence of moss because it is traversed by water continuously, reducing the performance of the fill pack.

Fill pack is used as a heat exchange between air and water so it must have good heat resistance. The material used in the fill pack is PVC because it is considered to have good heat resistance for water at certain temperatures. The fill pack is placed right under the sprinkle pipe and is associated with the concrete above it. The following is the fill pack design data used as a place for heat exchange from air and water, including:

Table 2. Fill Pack Design Data

General	
Dimensions	Width 15.240 m; Length 15.240 m; Depth 1.52 m
Film Space & Thickness	17 mm; 0.381 mm
Unit Surface	149.9 m^2/m^3
Air Velocity In Fill	2.54 m/s
Fill Plot Area / Cell	231.45 m^3
Live Load (min. 125 kg/m^3)	293 kg/m^3
Fire Resistance	25 or Less Flame Spread as per ASTM-E48

Calculation of cooling effectiveness has several formulas and requires data on cooling tower inlet water temperature and cooling tower outlet water temperature. The following formulas are used in this study [11][12][13][14], including:

$$\text{Range (°C)} = [\text{TWR (°C)} - \text{TWS (°C)}] \quad (1)$$

$$\text{Approach (°C)} = [\text{TWS (°C)} - \text{TWB (°C)}] \quad (2)$$

$$\text{CE (\%)} = 100\% \times \frac{\text{range}}{\text{range+approach}} \quad (3)$$

Where *CE* represents cooling effectiveness (%), *TWR* is temperature cooling water return (ºC), *TWS* is temperature cooling water supply (ºC), and *TWB* is temperature wet bulb (ºC).

III. Results and Discussion

A. Results

Data collection is obtained before replacing the fill pack and also after replacing the fill pack. This is done in order to determine the effectiveness of cooling before and after the replacement of the fill pack produced in the cooling tower. Replacement of fill packs is carried out for 10 days in a state of death or not processing cooling water. Data before replacing the fill pack is obtained for 7 consecutive days and data after replacing the fill pack is also obtained for 7 consecutive days. The following is the water temperature data in the cooling tower obtained before and after the replacement of the fill pack, including:

Table 3. Water Temperature Data in Cooling Tower Before Fill Pack Replacement

No	Cooling Water Return (ºC)	Cooling Water Supply (ºC)	Temperature Wet Bulb (ºC)
1	40.897	33.808	29
2	40.625	32.196	29
3	42.225	32.931	29
4	42.337	33.473	29
5	41.283	32.742	29
6	40.625	33.519	29
7	40.840	33.026	29

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Table 4. Water Temperature Data in Cooling Tower After Fill Pack Replacement

No	Cooling Water Return (°C)	Cooling Water Supply (°C)	Temperature Wet Bulb (°C)
1	41.623	30.132	29
2	42.830	29.852	29
3	41.208	30.698	29
4	40.011	29.815	29
5	42.842	30.618	29
6	40.529	29.647	29
7	40.298	29.738	29

B. *Cooling Effectiveness of Cooling Tower*

Calculation of cooling effectiveness is used to determine the level of cooling tower efficiency in producing cooling water before it is distributed. There are 3 formulas used in finding the cooling effectiveness of the cooling tower. The first formula is to find the range value, the second formula is to find the approach, and the third formula is to find the cooling effectiveness:

Table 5. Calculation Results of Cooling Effectiveness in Cooling Tower

No	Range (°C)	Approach (°C)	Cooling Effectiveness (%)
Design Data			
1	12.5	3.9	76.220
Actual Data Before Fill Pack Replacement			
1	7.090	4.808	59.591
2	8.429	3.196	72.507
3	9.294	3.931	70.274
4	8.864	4.473	66.462
5	8.541	3.742	69.536
6	7.106	4.519	61.128
7	7.814	4.026	65.998
Average			66.5
Actual Data After Fill Pack Replacement			
1	11.491	1.132	91.035
2	12.978	0.852	93.840
3	10.509	1.698	86.089
4	10.196	0.815	92.597
5	12.224	1.618	88.308
6	10.883	0.647	94.390
7	10.561	0.738	93.472
Average			91.39

In table 5 it can be seen that the effectiveness of cooling after replacing the fill pack has an average of 91.39% while before replacing the fill pack has an average of 66.5%. Replacement of fill packs greatly affects the temperature of the water produced and water temperature can affect the effectiveness of cooling. If it appears that the water temperature rises slightly, it needs to be followed up. This is because the slightest influence of water temperature can have a big impact. The diagram below will show the difference in cooling effectiveness produced by the cooling tower. The comparison will involve design data, data before fill pack replacement, and data after fill pack replacement. The following is the comparison diagram:

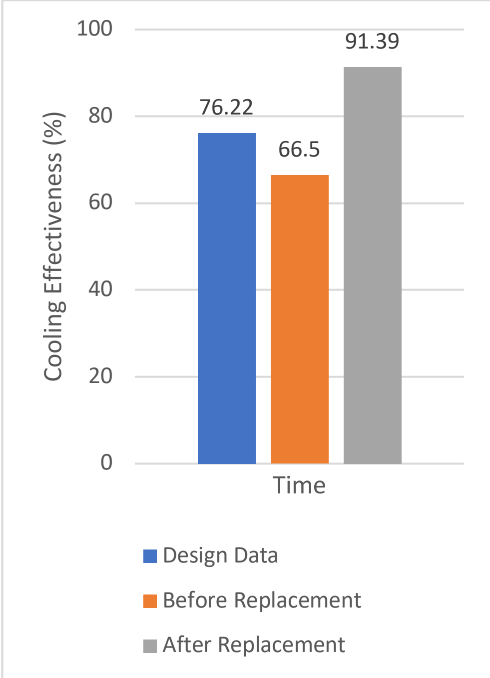

Figure 1. Average Comparison Diagram of Cooling Effectiveness

In the diagram above, it is found that the cooling effectiveness after replacing the fill pack is higher than the 1991 design data. This is due to the difference in the slope of the fan. In the design data collection, the fan slope is at 8° - 10°, while in the data collection before and after the fill pack replacement, the fan slope is at 12° - 15°. The tilt of the fan greatly affects the amount of air pull required. The fan can be tilted to a maximum of 30° but if it is tilted to the maximum, the motor that drives the fan will work bigger and require more power, and the effect will get the desired amount of air that is large. The more tilted the fan when tilted, the more air will be drawn into the cooling tower and this will speed up the water cooling process. The effectiveness of cooling before replacing the fill pack is very low because the fill pack is brittle, a lot of dirt, and torn, therefore it is necessary to check and replace the fill pack.

IV. Conclusion

Fill packs are replaced 2 to 3 times in 10 years depending on the quality of the fill pack used. Damage that usually occurs in fill packs such as moss growth that prevents water from flowing and makes the water temperature not maximized to be cooled and torn due to age and cannot withstand hot water flowing continuously. Based on the results of replacing the fill pack and the data from the calculation of the cooling effectiveness of the cooling tower, it can be concluded that the replacement of the fill pack greatly affects the effectiveness of cooling in the cooling tower as an equalizer of hot water sprayed by the spryer. The effectiveness of cooling before replacing the fill pack reaches 59% - 73%, but after replacing the fill pack it reaches 86% - 95%.

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Replacement of fill packs can affect water temperature after cooling by approximately 3ºC. The actual range before replacing the fill pack is at a value of 7 to 9, while the actual range after replacing the fill pack is at a value of 10 to 12. The actual approach before replacing the fill pack is at a value of 3 to 4, while the actual approach after replacing the fill pack is at a value of 0 to 1. If the cooling effectiveness is greater, it means the cooling tower performance is getting better [15]. In this cooling tower repair, not only the replacement of the fill pack is carried out but also the replacement of drift eliminators, so that the results in this study are not only influenced by the fill pack.

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