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Research article

Retroffiting and Repairing Cooling Tower Structure Within A Tide Deadline

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A B S T R A C T

This project focused on the retrofitting of an aging cooling tower at PT. Sulfindo Adiusaha's Chlor Alkali Plant. The goal was to incorporate advanced technology and features into the cooling tower, in response to regulatory modifications and the need to upgrade older buildings to improve their resilience and performance. The existing wood structure of Cooling Tower T 9120 GH was replaced with a new FRP structure, and the Fill Pack was also replaced during the retrofit to restore the cooling capacity to the original design. The project was completed within a tight timeline of 10 days to ensure long-term reliability of operations at the plant.

Following the commissioning of the new cooling tower structure, the retrofitted T 9120 GH cooling tower was able to deliver a cooling capacity of 10.8 million Kcal with an efficiency of 78.6%, indicating good condition and close to the original design performance. The maximum vibration data on the motor and base frame were recorded at 10 mm/s2, which is within the satisfactory category based on the CTI Standard. Motor bearing temperature was recorded at 65°C, indicating good performance.

This project demonstrates the importance of timely upgrades to maintain plant operations and ensure long-term reliability. Retrofitting an aging cooling tower can improve its functionality, efficiency, and environmental impact. The success of this project also highlights that retrofitting can be done within a tight timeline, without compromising on safety or quality, provided proper planning and execution are in place.

1. INTRODUCTION

Retrofitting involves adding new technology or features to an old system, which helps to avoid total system replacement. This process is often triggered by regulatory changes or the need to enhance the resilience and performance of aging buildings. Investments in building structures need to consider environmental concerns, such as climate change, by reducing negative impacts, including emissions and environmental impacts of buildings. Retrofitting also promotes healthier indoor environments during extreme weather conditions. Additionally, retrofitting contributes to the circular economy by reducing the production of new items, which in turn reduces environmental impact and emissions through recycling.

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There have been numerous efforts to retrofit cooling tower buildings, including the use of 3D numerical simulation by Yang [1] to analyze performance improvements through increased resistance of the packing coefficient and obtaining two-phase flow characteristics. To enhance cooling tower efficiency, it is crucial to accurately measure water consumption in relation to flow rate and water conditions, as well as operate at appropriate air flow rates and water conditions. Cooling tower operators can analyze water usage techniques and implement methods [2] to improve cooling tower performance and achieve higher efficiency. Precision wet and dry air passage arrangements are often utilized in cooling tower repairs. Modifications to cooling towers aim to reduce fan power consumption and air requirements. Dehaghani [3] et al. used fan rotation adjustments based on airflow needs to regulate airflow and prevent sudden fluctuations in fan power. This approach reduced fan power consumption by 64.6% and water consumption by 9.4%. The modifications made to the cooling tower resulted in satisfactory performance. Kim [4] developed an automated approach for investigating the interaction between cooling tower performance and cooling water network design, allowing for more efficient retrofit designs of cooling water systems. Their approach involved reusing cooling water between different coolers, debottlenecking the task cooling system.

The Chlor Alkali Plants at PT. Sulfindo Adiusaha are equipped with Cooling Tower T 9120 GH Marley Brand Type W4444-6.0-2 Conterflow Type, which has been in operation since 1997. Due to aging and environmental factors, the wooden structure of the cooling tower has started to deteriorate. To ensure the long-term reliability of the cooling tower, PT. Sulfindo Adiusaha carried out a retrofit by replacing the wooden structure with an FRP structure and replacing the fill packing. The cooling tower plays a crucial role in the factory process as it acts as a coolant. Furthermore, replacing wood with FRP is expected to address environmental issues, reduce emissions, and make buildings healthier during extreme weather conditions. Retrofitting activities can only be carried out during Turn around or short Shutdown periods as the cooling tower is the primary cooling device at the Chlor plant.

During the planned 2021 Turnaround at the Chlor alkali plant PT. Sulfindo Adiusaha, there is a limited time frame of only 13 days, of which 10 days are allocated for the retrofit of Cooling Tower T 9120 GH. This means that all retrofitting activities, including the dismantling of the old cooling tower, cleaning of the cold water basins, installation of new structures and fill packs, and installation of mechanical and electrical components must be completed within this short time period.

2. LITERAURE REVIEW

Cooling towers can be classified in various ways, including by airflow, airflow direction, shape, heat transfer method, and construction. Each type is designed and manufactured to meet specific needs and requirements, with unique advantages and limitations. Therefore, it is crucial to have a comprehensive understanding of the various types of cooling towers [5].

2.1 Working Principle of Cooling Tower. Repair

The primary function of cooling towers is to cool water through evaporation, which is why they are also referred to as "evaporative coolers". Industrial processes often rely on cooling towers to remove heat from water by allowing it to mix with air, which is then removed from the tower, carrying the transferred heat with it. Though evaporative condensers follow the same process, they can vary in design and usage. However, this cooling process requires a considerable amount of water, which is used to maintain water quality. While there are empirical formulas to calculate the amount of water consumed due to evaporation, the general rule of thumb is to assume that about 1% of the water flow rate is evaporated for each degree of cooling achieved at ambient temperature. Although this rule of thumb is widely followed, it is not an accurate method for evaluating water consumption as it does not account for ambient conditions.

At a chlor-alkali plant, the cooling tower plays a crucial role in cooling process water from all the heat exchangers in the plant. The cooling process in a cooling tower is based on the principle of evaporative cooling. As water comes into contact with air, it undergoes a heat transfer process which results in the removal of heat from the water through evaporation. During this process, a small amount of water is lost due to evaporation. When air is blown through or against the flow of water, it comes into contact with the water droplets which are at a higher enthalpy. As a result, the air causes the evaporation of water droplets, leading to the exchange of latent heat and conversion of water droplets into vapor form. The removal of sensible heat causes the remaining water droplets to drop in temperature and cool down.

2.2 Types of Cooling Tower Materials

Cooling towers can be classified into various types based on their assembly method, construction materials, heat transfer method, air movement pattern, and way of air movement. It is important to have an understanding of these different types of cooling towers in order to choose the right one that meets the specific cooling needs of an industrial process.

Wooden Cooling Towers

Wooden cooling towers have been a popular choice due to the abundance of wood as a material, its affordability, workability, and durability under harsh operating conditions. Historically, wood has been the primary material for cooling tower construction until the introduction of FRP/plastic structural materials.

Iron Cooling Towers

Steel construction is a popular choice for small and medium-sized cooling towers designed for factory assembly. Local building and fire codes may also require larger cooling towers to be made of steel. Galvanized steel is commonly used for the structure, chilled tubs, partitions, decking, fan cylinders, and other major components. In some cases where the severity of the application is extreme, stainless steel can be used, although this option comes at a high cost. Despite the high cost, the performance of stainless steel towers is significantly improved compared to other materials.

Concrete Cooling Towers

Concrete cooling towers are constructed using reinforced concrete which makes it highly resistant to aggressive water. The combination of concrete and iron reinforcement provides excellent tensile and compressive strength, making it capable of carrying heavier loads compared to other materials. Additionally, concrete offers superior fire-resistant properties, making it ideal for high-risk environments. Although the initial construction cost may be higher, the advantages in terms of load-bearing capacity and superior vibration absorption capabilities make it acceptable.

Cooling Tower FRP

Fiberglass-reinforced polymer (FRP) cooling towers are made from lightweight, durable, and corrosion-resistant materials. FRP is considered a composite material due to its combination of materials that enhance its performance. FRP is a popular and practical alternative to traditional cooling tower materials such as wood, concrete, or steel. It has unique advantages, including the ability to mold it into complex shapes and sizes in a single piece. Due to growing awareness of environmental conservation, the use of FRP is on the rise, making it the most sustainable and sensible choice for modern cooling tower construction.

3. METODOLOGI

The use of FRP products not only provides superior performance but also contributes to reducing environmental impacts. This is because FRP has the potential to prolong the lifespan of structures and resist the adverse effects of harsh environments, weathering, degradation, and aging. Compared to concrete, iron, and steel, FRP has been reported to be more sustainable. Additionally, FRP is environmentally friendly due to its excellent corrosion resistance. In harsh environments, FRP can effectively replace steel bars, which solves the durability problem of concrete structures. Overall,

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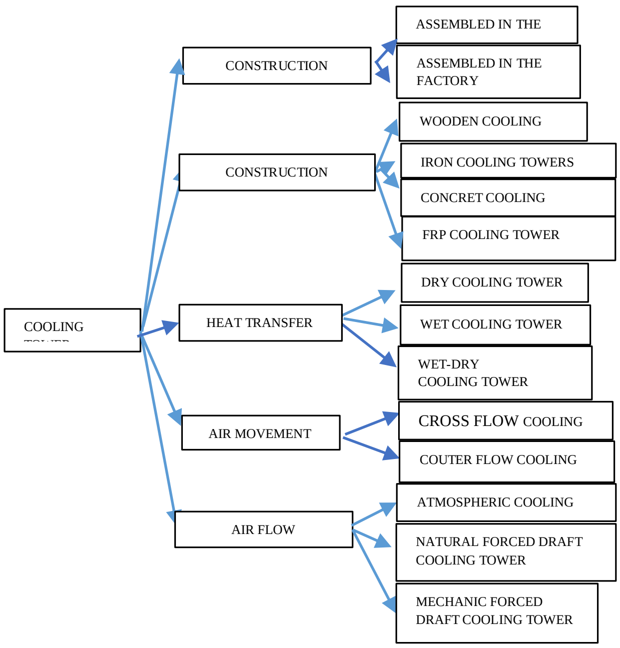
FRP products are an excellent choice for reducing the environmental impact of cooling towers.



Picture 1. Types of Cooling Tower

During the installation of the Retrovit Cooling tower T 9120 G and H, the Erector set documents from the manufacturer, SPX Cooling Technologies [8], are followed as a guide. SPX Cooling Technologies emphasizes three crucial factors that should be considered when erecting an FRP Counterflow Cooling Tower, which are:

3.1. Minimum safety standards.

The following points outline the minimum safety standards for worker protection during the construction process, although they may not cover all potential emergency situations that may arise.

A. Personal Protective Equipment:

The minimum recommended Personal Protective Equipment (PPE) should cover areas such as the eyes, head, face, feet, hands, and provide splash protection and fall barriers.

B. Work Protection at Height:

Fall protection equipment is mandatory at all times when working at heights where workers may fall or work at a height of 6 feet (1.8 meters) or more. The body harness used must be equipped with an absorber having a double lanyard.

C. Anchorage Points:

Qualified personnel must identify suitable anchor points, which should comprise double girts and/or columns above the girt intersections. A single girt cannot function as an anchor point.

3. 2 Installation Quality Control.

If a cooling tower is installed improperly, it can negatively impact its thermal capacity. Therefore, SPX only guarantees the thermal performance of cooling towers that have been constructed under the following conditions:

a. Installation carried out by an SPX crew

b. Installation done by a non-SPX crew under the guidance of an SPX field supervisor

c. Installation done by a non-SPX crew approved by SPX, provided that they have relevant experience and can demonstrate technical proficiency

d. Installation done by a non-SPX crew under the instructions of a non-SPX field supervisor who has been trained and approved by SPX for the project.

It's important to note that this is only a minimum requirement for thermal performance guarantees, and other factors may also impact the cooling tower's efficiency.

3.3 Installation Stages

The installation sequence recommended by the manufacturer is crucial for the successful erection of a cooling tower. However, modifications to the sequence may be necessary due to site conditions or erection methods. The following is a list of installation steps, including transverse and longitudinal bend installation, base plate anchor installation, header pipe installation, fan deck installation, access ladder installation, cell partition installation, fill pack installation, distribution pipe installation, spray system installation, outer casing installation, mechanical and electrical equipment installation, fan stack installation, drift eliminator installation, and access stairs and handrail installation. To complete this retrofit activity within 10 working days, careful planning is required, and modifications may be necessary to adjust to construction time and site conditions.

The work process is divided into three main stages: preparation, construction, and startup commissioning. The preparation stage includes several activities such as a kick-off meeting, material inspection at the warehouse, site survey, mobilization of materials to the worksite, and gluing of fill packs (Figure 2).

Figure 2 Fill packs after finishing glue

Figure 3. When installing scaffolding on a cooling tower

Following the preparation stage, the construction stage begins, which involves various tasks such as scaffolding installation (Figure 3), dismantling of the old cooling tower, installation of FRP structures, mechanical and electrical equipment, and alignment of gear boxes and motors. Finally, the Startup Commissioning stage involves testing the cooling tower's operation without water circulation and then with coolant circulation. Upon completion of all these stages, the project is declared finished. However, in case any discrepancies arise from the original plan, an inspection and repair will be carried out to ensure that the work meets the required standards.

In order to meet the project timeline, the work is being conducted around the clock in two shifts. High-capacity cranes are being utilized for the removal and installation of mechanical and electrical equipment, fan stacks, and axial fans. The rigging study has indicated that a crane with a capacity of 50 tons is necessary for the project.

4. RESULT AND DISCUSSION

4.1 Operational conditions of the motor during the test

The retrofit process was completed successfully three days before the end of the scheduled turn around. However, the service fluid had not yet been circulated in the piping system, which necessitated a running test of the Cooling tower without the fluid circulation. The running test was conducted to evaluate the results of the retrofit work, including the measurement of vibrations on the motor and motor frame base, as well as data on the operational conditions of the motor during the test. The results of measurements of motor vibration on cooling towers H and G can be seen in Tables 1 and 2.

Tabel 1. Vibrasi T 9120 G

T 9120 G (After *retrovit*)									
NO	Motor DE			Motor NDE			Base Frame		
	Vertical	Horizontal	Axial	Vertical	Horizontal	Vertical	Horizontal	Axial	
	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	
1	10.1	16.9	12.2	15.1	18.4	11.8	18.9	5.1	
2	9.2	15.3	13.1	14.6	16.2	10.9	17.2	5	
3	9.8	16.1	12	15.3	17.8	11.9	17.7	5.3	

Tabel 2. Vibrasi T 9120 H

T 9120 H (After *retrofit*)								
NO	Motor DE			Motor NDE		Base Frame		
	Vertical	Horizontal	Axial	Vertical	Horizontal	Vertical	Horizontal	Axial
	mm/s²	mm/s²	mm/s2	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²
1	2.4	2.6	3.8	4.5	2.8	2.1	3.7	1.5
2	2.5	3.1	3.7	5.3	2.9	2.1	3.9	1.4
3	2.4	2.3	3.7	5.3	2.5	2.1	4.1	1.4

The vibration data collected from the drive end and non-drive end of the motor, as well as the Base Frame measurement results, indicate that the

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vibrations fall within the acceptable limits for Cooling tower T 9120 H, and the Alert and Danger conditions for Cooling tower T 9120 G, as defined by the Cooling Tower Institute (Table 3). These results suggest that the retrofit has been successful in maintaining the tower's performance and ensuring safe operation.

Tabel 3. CTI standard for vibration limit

Vibration Limit refer to CTI Standard for Long Hollow Drive Shaft *Cooling tower*			
Good	Satisfactory	Alert	Danger
mm/s²	mm/s²	mm/s²	mm/s²
< 6.8	6.8-10.8	>10.8-16.2	>16.2

Despite the completion of the retrofit process, a certain vibration value is still exceeding the safe operating limits of the cooling tower. As a result, an alignment procedure is necessary to bring Cooling Tower T 9120 G within the satisfactory range (Table 4).

Tabel 4. Data Running Cooling Tower without service fluid circulation

Data Running Cooling Tower without service fluid circulation										
	T 9120 G					T 9120 H				
NO	DATA MOTOR			Bearing Temp		DATA MOTOR			Bearing Temp	
	P	RPM	ARUS	DE	NDE	P	RPM	ARUS	DE	NDE
	KW		A	0C	0C	KW		A	0C	0C
1	45	1500	64.9	52.2	44.5	45	1500	70	62.2	48.6
2	45	1500	65	55	47.4	45	1500	70	66	51
3	45	1500	65	57.1	52	45	1500	69.9	69.4	53

Table 4 shows that the running test performed without any cooling load is not an accurate representation of the actual operating conditions of the cooling tower. The motor current data during this test is only 60% of the motor current data stated on the name plate. This is due to the fact that the motor load during the running test without cooling load is generated solely from the air resistance that is drawn by the axial fan, resulting from friction between the air and the fill pack surface. Moreover, during this test, the gaps between the fill sheet sheets in the fill pack are still relatively wide.

4.2 Running test with service fluid circulation

One day before the end of the turnaround implementation schedule, a Realignment was conducted on Cooling Tower T 9120 G. Subsequently, a Running test was performed again with the service fluid circulating in the system (Table; 5, and 6).

Table 5. Vibration of T 9120 G after realignment.

T 9120 G (After retrovit)								
NO	Motor DE			Motor NDE		Base Frame		
	Vertical	Horizontal	Axial	Vertical	Horizontal	Vertical	Horizontal	Axial
	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²
	2.5	4.6	3.4	4.7	3	4.7	2.4	2.2
2	2.2	5	3.5	5.1	3.5	4.9	3	1.6
3	2.7	4.7	4	5.9	3.1	4.5	3.1	2.4

Tabel 6. Vibrasi T 9120 H

T 9120 H (After retrovit)								
NO	Motor DE			Motor NDE		Base Frame		
	Vertical	Horizontal	Axial	Vertical	Horizontal	Vertical	Horizontal	Axial
	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²	mm/s²
1	4.3	7.4	5.2	8	8	4.3	9.2	3.7
2	5.1	6.5	6	6.9	7.7	5	9	4
3	4.6	7	5.6	8.3	7.9	4.1	10	4.6

The analysis of the motor vibration data on both the drive end and non-drive end, as well as the vibration data on the Base Frame measurement results following the running test with fluid circulation service, revealed that the vibrations remained within the acceptable limits for Cooling tower T 9120 G and T 9120 H.

The analysis of the motor vibration data on both the drive end and non-drive end, as well as the vibration data on the Base Frame measurement results following the running test with fluid circulation service, revealed that the vibrations remained within the acceptable limits for Cooling tower T 9120 G and T 9120 H (Table 7).

Table 7. Motor running test data with fluid service

Data Running test Motor dengan fluida service				
	T 9120 G		T 9120 H	
NO	DATA MOTOR	Bearing Temp	DATA MOTOR	Bearing Temp

	P	RPM	ARUS	DE	NDE	P	RPM	ARUS	DE	NDE
	KW		A	^{0}C	^{0}C	KW		A	^{0}C	^{0}C
1	45	1500	84.6	42.1	41.5	45	1500	85	58.8	52.1
2	45	1500	84.6	46	44.9	45	1500	85	63.1	53.9
3	45	1500	84.6	58.3	50.3	45	1500	85	65	56.7

Based on the above data, it is evident that the G and H Cooling Tower motor is still functioning within its intended operating range. This is indicated by the motor current value, which is below the value indicated on the name plate, and the bearing temperature, which falls within a suitable operating temperature range when compared to the Bearing operating temperature chart.

4.3 Efficiency of the cooling tower

Efficiency measurement of the cooling tower is determined by its range and approach. The ambient wet bulb temperature sets the limit for cooling tower efficiency. While it is ideal for the cold-water temperature to be the same as the wet bulb temperature, this is practically impossible to achieve. Attempting to achieve this requires constructing very large towers, resulting in significant evaporation and current losses, making it impractical. In practice, cooling tower efficiencies range between 70 to 75%. The efficiency test results of the cooling tower can be found in Table 8.

Table 8. Efficiency of Cooling tower T 9120 H

Performance								
T9120GH	N0	Flow	T in	T out	wbt	Approach	Range	ε
After Retrofit	1	1320	37.65	29.67	27.50	2.17	7.98	78.62%
	2	1320	37.9	29.69	27.40	2.29	8.21	78.19%
	3	1320	37.9	29.67	27.40	2.27	8.23	78.38%
Design		2000	39	30.00	28.00	2	9	81.82%

The efficiency under design conditions is 95.81%, which is 4.18% below the target standard. The reason for the lower efficiency value is due to the fact that the mechanical and electrical components were not replaced, causing the cooling tower to operate under less-than-ideal conditions. Additionally, differences between the operating environment and the manufacturing environment could also have contributed to the lower efficiency value. It is important to note that achieving 100% efficiency according to the design is not always feasible in practical operating conditions.

Table 9. Cooling capacity Cooling tower T9120H

Cooling capacity							
T9120GH	Date	Flow	T in	T out	Wbt	Q	
After Rretrofit	21 Agustust 2021	1320	37.65	29.67	27.50	10,533,600	Kcal
	22 Agustust 2021	1320	37.9	29.69	27.40	10,837,200	Kcal
	23 Agustust 2021	1320	37.9	29.67	27.40	10,863,600	Kcal
Design		1320	39	30.00	28.00	11,880,000	Kcal

The data indicates that the G and H Cooling tower motor is performing relatively well in terms of cooling capacity (Table 9). However, there is room for improvement in terms of optimizing its performance to reach the ideal operating conditions. Some measures that could be taken to achieve this include conducting regular maintenance and replacing any outdated or worn-out mechanical and electrical components. Additionally, monitoring and controlling the operating environment to ensure that it aligns with the manufacturing work environment could also help in achieving optimal performance.

5. CONCLUSIONS AND RECOMMENDATION

Considerations related to capacity, effectiveness and efficiency, reinforcement has been achieved and completed, in addition to considering environmental issues such as climate change, reducing greenhouse gas emissions, minimizing adverse impacts on the environment, improving building health, and reducing pollution through recycling can be achieved.

The Retrofit process for Cooling Tower T 9120 G and H was successfully completed within the scheduled 10 calendar days. The results of the Running Test and commissioning implementation indicate that the mechanical components are operating within the satisfactory range according to CTI standards, with maximum vibrations of 8.3 mm/s. The electric motor, which serves as the axial fan drive, exhibited good operational conditions during the running test, as indicated by the measured current value, which was below the standard name plate. Additionally, the measured

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bearing temperature on the drive end and non-drive end fell within the good range according to the bearing operational temperature graph.

During the running test, the cooling tower was able to achieve a cooling capacity of 10.8 million Kcal with an efficiency of 78.6%, which is close to the design value of 11.8 million Kcal and 81.8% efficiency. However, this value was not fully achieved due to the mechanical and electrical components that were not replaced, leading to suboptimal performance. Additionally, the difference between the operating and manufacturing environment may have also contributed to the difference in performance. To achieve the desired performance, a longer and well-planned retrofit process should be carried out during normal working hours to ensure proper work and supervision. Furthermore, the replacement of mechanical and electrical equipment with new units is necessary to bring the cooling tower back to its ideal condition based on the design parameters.

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