

Evaluating the Effectiveness of Chosen Maintenance Strategies for Dedicated Equipment

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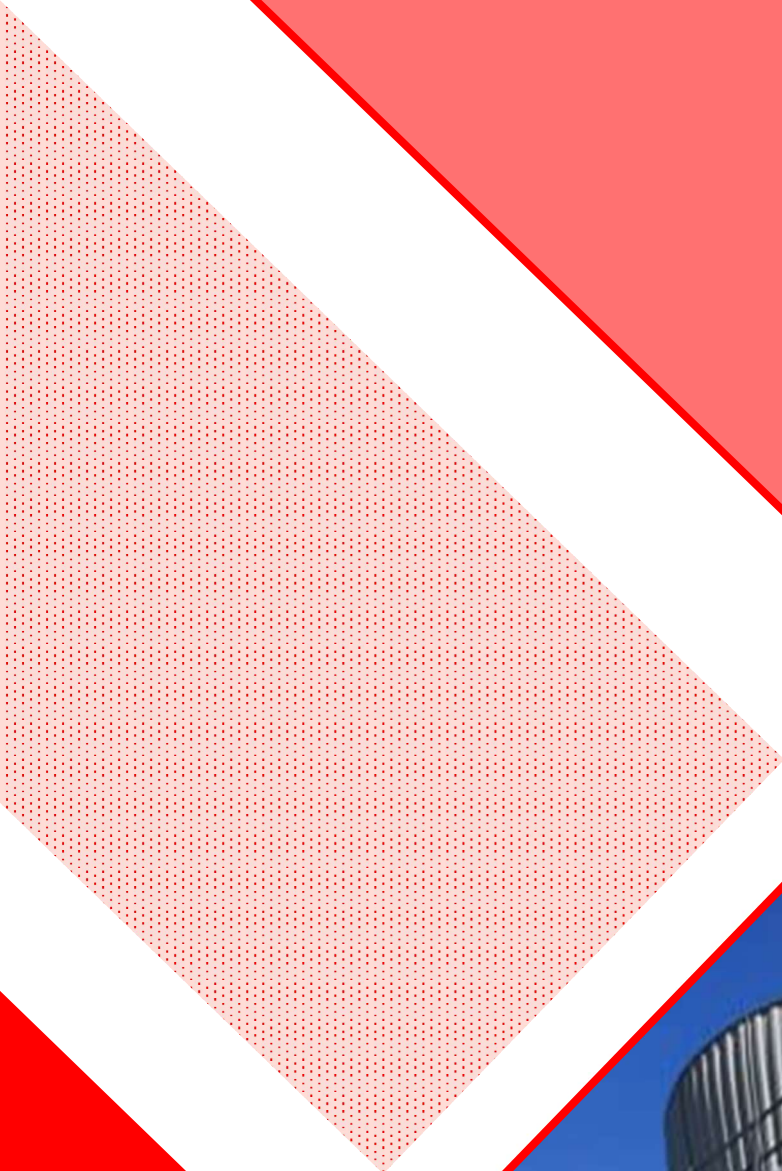


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Introduction

In this assignment I will be evaluating the current maintenance strategy for the fin fans on the cooling tower water treatment system. Following an explanation of the fans, I will perform a critical study of the current care procedures and discuss the efficiency of said strategy. Finally, I will provide my solutions for how to improve the maintenance procedures with considerations to costs and resources.

Current Practices

General Function

The Cooling towers on the Dow site serve as part of the process water treatment system. The general purpose of the cooling towers is to take the hot process water from the many processes on site and remove as much of the heat as possible before returning the water back to those processes. This cycle is very important as the effectiveness of the towers has an impact of the efficiency of these plants.

The water sent to the different plants is typically used on heat exchangers and other equipment that require some form of cooling/temperature management. If the water is not cooled down enough, it can lead to other plants failing to reduce the temperatures of other systems or materials. This could in turn lead to a plant experiencing a form of failure that requires the plant being shut down temporarily. For example, if a heat exchanger received hot water from the cooling towers, it couldn't then efficiently cool down the process materials within the exchanger and the heated materials can cause problems, such as overheating, further down the system.

Literature supplied in Dow (R. Jones, 2019) indicate that the cooling tower will reduce the temperature of the water to approximately 68.57% of the original temperature.

The cooling tower is a primarily wooden structure that houses six large fin fan systems on top of it, powered individually by a large motor. The hot water is fed into the top of the cooling towers and is allowed to freely flow down the internals of the tower structure until it reaches the collection vat at the bottom, where it can then be treated and then pumped back into the various systems on site.

The primary focus of this assignment is to look at the current maintenance procedures for the six fans. The primary goal of the fans is to extract and expel as much heat from the water as possible, cooling it down. The formation of the tower structure is designed to encourage greater area contact between the hot water and the cooler air that is produced by the fin fans.

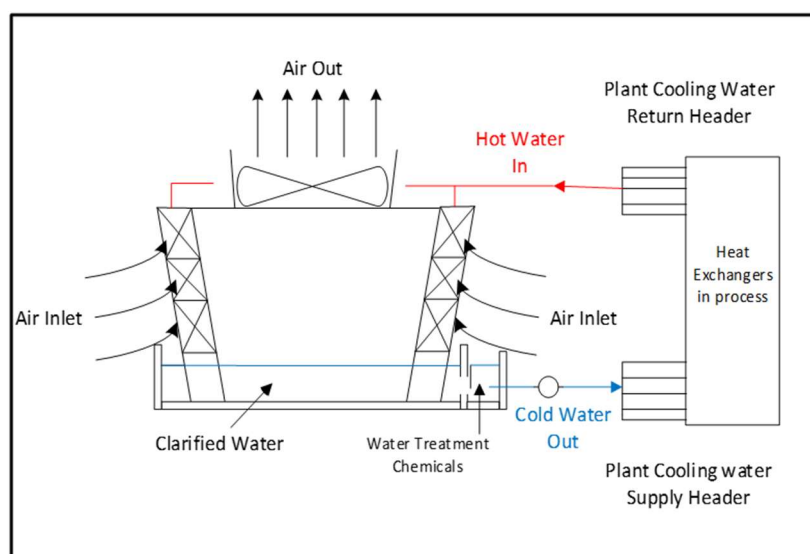


Figure 1. (Dow Corning, 2014)

Current Maintenance Practices

As mentioned, the cooling tower has six major fans which operate independently via their own motors. The six fans continuously work throughout the summer months when general temperatures are higher, and then only operate three of the fans during the winter months. This means that during the winter, it is possible to perform planned maintenance tasks during these winter months. It would be an inconvenience to have the fans down at anytime during the hotter months as any downtime then could cause problems for the other plants.

Planned Maintenance

Tower fans will have planned maintenance tasks performed every two years during the winter months as per the maintenance guide (W.J Riseborough, 2013).

The main tasks include:

- Motor removal for testing/replacement
- General condition monitoring of the fan blades

The general planned maintenance tasks are generally something that lasts for a period of two to three weeks. Due to only needing only the three fans during the winter period, three of the motors can be removed and maintained at a time. Once these have been returned, the other three motors can also go through maintenance and then also replaced. Meaning, in the best-case scenario, the cooling tower will be at half efficiency for only a small duration through the year.

Whilst there is a benefit to having very little downtime, this does mean the equipment is left running for long periods during the summer months. This is relying on the equipment to stay functional for up to six or more months without a breakdown.

If several fans were to go down during the summer months, it could mean the cooling tower will not operate effectively enough to cool the water supplies in the system. This indicates a need to provide improvements when it comes to providing a better breakdown maintenance plan.

Condition Based Monitoring

Condition-based monitoring is conducted every month on the motors for each operating fan. This is completed using vibration analysis equipment and visual inspections. The data retrieved from the vibration readings is compared to other past readings to pick up any trends or anomalies. When readings become irregular or reach a certain threshold, the system flags the readings so that they can be better investigated, and preventative maintenance can occur.

The main benefit of using these techniques is that it allows for potential issues to be picked up on early and can be rectified before the any failure risks become hazards. An ongoing trend can also indicate if one of the motors could be reaching their end-of-life cycle. Meaning that reactive maintenance actions, such as preparing/purchasing a spare motor for replacement, can occur promptly and reduce operation downtime. This is especially beneficial during those summer months when all six fans are required.

Another benefit of this method is the increased reliability of the motors. The monthly checks also allow for activities that can be performed whilst the equipment is active, such as oil top ups and other general activities. These small but frequent tasks help to increase the lifetime of the equipment and reduce downtimes.

A drawback of this method is that it requires more man hours to be used to complete. This requires someone to use several hours a month to collect the vibration readings and analyse them. Whilst this does provide valuable information, it does require the initial capital to purchase and maintain the monitoring equipment. It also takes time to train personnel to operate and understand the equipment.

Reliability of the current system

Individual fan reliability calculations

Looking at existing maintenance reports (Dow, 2015-2023) for the six fans on the cooling tower for the past eight years. I have taken the historical failure rates for each of the motors and worked out the annual failure rate for each fan in the below table:

	Fan 1	Fan 2	Fan 3	Fan 4	Fan 5	Fan 6
Total Failures	4	5	8	10	5	4
Per year	0.5	0.625	1	1.25	0.625	0.5

Table 1: (Knight, 2024)

I have taken the annual breakdown rates for each fan and worked out the reliability rates, the below figures are the results:

Reliability Rate Equations	
$FR1 = \frac{0.5}{8760} = 5.708^{-5}$ $R1(1000) = e^{\lambda t}$ $R1(1000) = e^{-5.708 \times 10^{-5} \times 1000}$ $R1(1000) = 0.95$	$FR2 = \frac{0.625}{8760} = 7.1347^{-5}$ $R2(1000) = e^{\lambda t}$ $R2(1000) = e^{-7.1347 \times 10^{-5} \times 1000}$ $R2(1000) = 0.93$
$FR3 = \frac{1}{8760} = 1.142^{-4}$ $R3(1000) = e^{\lambda t}$ $R3(1000) = e^{-1.142 \times 10^{-4} \times 1000}$ $R3(1000) = 0.89$	$FR4 = \frac{1.25}{8760} = 1.427^{-4}$ $R4(1000) = e^{\lambda t}$ $R4(1000) = e^{-1.427 \times 10^{-4} \times 1000}$ $R4(1000) = 0.87$
$FR5 = \frac{0.625}{8760} = 7.1347^{-5}$ $R5(1000) = e^{\lambda t}$ $R5(1000) = e^{-7.1347 \times 10^{-5} \times 1000}$ $R5(1000) = 0.93$	$FR6 = \frac{0.5}{8760} = 5.708^{-5}$ $R6(1000) = e^{\lambda t}$ $R6(1000) = e^{-5.708 \times 10^{-5} \times 1000}$ $R6(1000) = 0.95$

Table 2: (Knight, 2024)

Individually each of the fans currently have very high reliability rates with all results being in the high 80's to mid-90's. Meaning that in terms of industrial standards, these are all world class figures.

Total system reliability calculations

With the previous calculations I have worked out the reliability figures for the overall system of six fans. However, there are two formations of this process to calculate. The overall system works differently depending on the time of year.

Winter Months

During the winter months the reliability of the system is simultaneously shared amongst the fans, meaning that minimal effort from the fans is required for the system to function correctly.

The diagram below shows the system represented in a parallel format. This is due to the system being able to still work efficiently for as long as one of the motors are in operation.

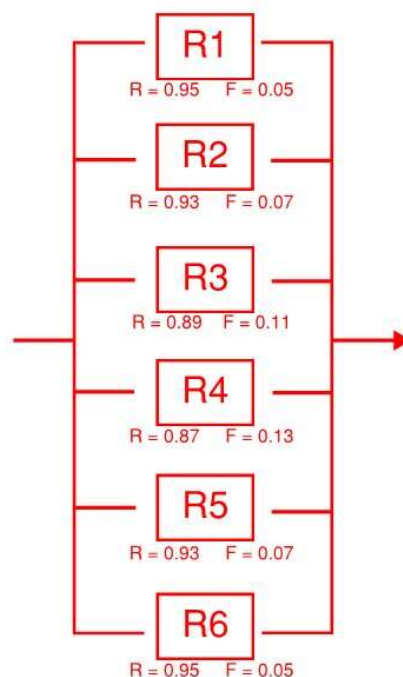


Figure 2. (Knight, 2024)

System Reliability Rate

$$R_s = 1 - [(1 - 0.95) \times (1 - 0.93) \times (1 - 0.89) \times (1 - 0.87) \times (1 - 0.93) \times (1 - 0.95)]$$
$$R_s = 0.9999 = 99.99\%$$

System Failure Rate

$$F_s = 1 - [(0.95) \times (0.93) \times (0.89) \times (0.87) \times (0.93) \times (0.95)]$$
$$F_s = 0.0001 = 0.01\%$$

Summer Months

The summer months require all the fans to be working efficiently. However, looking into historical documentation, the system can run at an acceptable level of efficiency with only three fans working. Although, this is not a sustainable level during the peak of summer. For as long as three fans remain operable, the system should not fail.

This is represented in the diagram below via the use of Parallel and series formats. For as long as one of the series of three is functioning, the system can function to a satisfactory level.

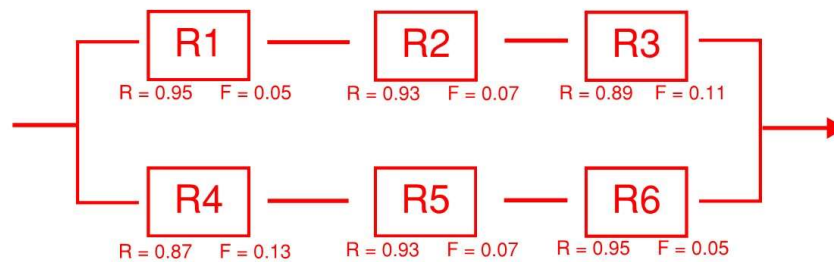


Figure 3. (Knight, 2024)

System Reliability Rate

$$R_{1,2,3} = 0.95 \times 0.93 \times 0.89$$
$$R_{1,2,3} = 0.7863$$

$$R_{4,5,6} = 0.87 \times 0.93 \times 0.95$$
$$R_{4,5,6} = 0.7686$$

$$R_s = 1 - [(1 - 0.7863) \times (1 - 0.7686)]$$
$$R_s = 0.9505 = 95.05\%$$

Summary

Unsurprisingly, the results show that with the additional constraints of requiring all the fans during operation during the summer months; the overall reliability factor is lower than that of the winter months. The more relaxed operation schedule of the winter months means that the risks of the system failure are far less. It is worth noting that the summer months do still have a very high reliability rate.

Bathtub Curve

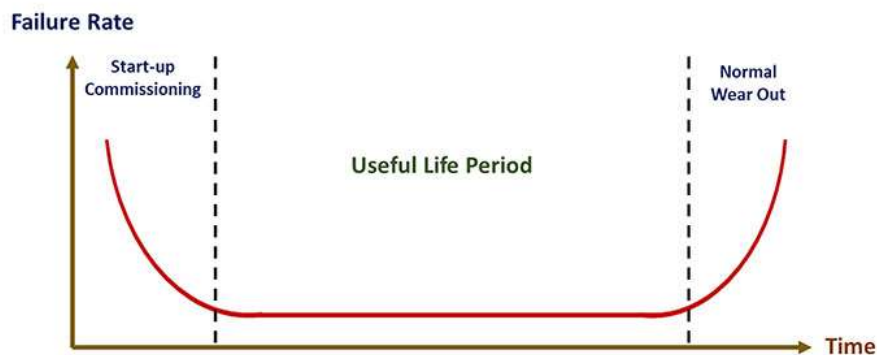


Figure 4. (Livoti, 2018)

In the above diagram, the bathtub curve is used to illustrate the general failure rates that can occur to a piece of equipment during its lifecycle. It is split up into three main phases:

Early life phase

A high chance of a failure occurs in the early stages for a couple of reasons. This can be due to design errors, installation issues or manufacturing defects.

Useful Life Phase

Once the turbulent early stage has passed, the equipment will often run as normal. Issues that arise in this phase are typically due to random and unpredictable failures. This can be mitigated through proper maintenance activities.

Wear Out Phase

As the equipment enters its final days, it will begin to succumb to general wear a tear. Predictive and condition monitoring techniques will be able to pick up on the early signs of this phase. This is where tasks can be planned to prevent the equipment becoming a breakdown maintenance task.

Maintenance Improvements

Reviewing these findings, it is clearly important to make sure that the strategies going forward are heavily focused on ensuring the cooling towers remain operational during the summer months.

Strategy Improvements

Predictive Maintenance

Predictive Maintenance methods currently include having a person go out to the motors and manually taking readings of each of the operating motors. A way to streamline this could be to install data collection sensors on the motors key points.

Benefits of this includes:

- Less man hours are required for an individual to acquire the readings.
- The readings are constant and allow for live readings to be viewed at any time. Meaning that reactive maintenance planning can begin at the earlier signs of a failure risk.
- Data can be viewed remotely from other locations other than the office space.
- Maintenance can be better planned as patterns in readings become more apparent over longer periods of time. This can help to mitigate the amount of downtime is required for crash maintenance tasks.

Spare Part optimisation

Currently the site does not keep spare motors on site and relies on the maintenance tasks completed during the winter months to keep the motors functional. This does mean that the site does not need to purchase additional motors, but this does pose a major risk during the summer months.

Prior to the summer months, additional parts for regular bad actors, such as couplings, should be stocked up with the anticipation of a potential breakdown. Based upon the maintenance history, parts that have proven to fail more frequently than others can have inventory pre-purchased in quantities that correlate with the likelihood a spare will be needed. For instance, consumables like bolts and lubrication can be stored in larger quantities than couplings.

A spare motor would also be highly beneficial. Having a spare motor that can easily be swapped out readily would provide a huge advantage for the plant as they could continue to run as normal whilst the other motor is being maintained.

However, this would require additional upfront capital from the site to obtain and store the spare. Additionally, a large enough storage location will need to be created and managed.

Training and Skills Development

Another option is to look at the current skill quality of the workforce. Developing a training programme that looks to enhance the technical skills of the maintenance team can help to reduce the number of mistakes that can occur during the maintenance task.

It would also have additional benefits such as increased safety compliance during activities.

Drawbacks to this can include:

- The time it would take to produce the new training programme.
- An additional cost to have a skilled trainer teach other members of staff. This would also include the man hours it would take to host the lecture.
- The amount of man hours required from each trainee who goes through the class.
- Documentation to record the completion of the training will need to be stored and curated by a training co-ordinator.

Conclusion

The current maintenance practices in Dow are already at a high standard in terms of the motors on the cooling tower. With a reliability rate of 99.9% and 95.05% in the winter and summer months respectively, there are already some adequate preventative methods in place to ensure equipment does not reach a breakdown failure.

However, this discussion has highlighted a few potential improvements that can still be made.

In the short term, providing additional training to those in the maintenance workforce can help to reduce the amount of amount of early life failures. Ensuring that the equipment is installed and calibrated correctly can also help to increase the equipment's general lifespan.

In the Medium term, the optimisation of the management of spare parts to ensure a sufficient inventory exists in a safe place in case any crash work occurs. Developing a system for those who manage the stock levels to know when parts need to be replenished and to increase stock levels in the summertime where failures will have greater impact.

The Long-term changes that can be made include investing in new technologies, such as sensors built into the motors that will continuously feedback information on the health of the equipment. Investment in high-cost spares such as spare motors would also be beneficial. These options would require greater levels of capital to complete.

Overall, there is always room for improvement when it comes to maintenance. As technology continues to advance and others resume to strive for greater efficiencies, there will always be a better way to complete a task.

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