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Optimization Of Boiler Feedwater Treatment Through Varies Softener Regeneration Process Inlet Pressure

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Abstract: Water softeners are the common method for treating the properties of boiler feedwater to prevent scaling and corrosion from forming inside the boiler. Softener regeneration processes are essential to regenerate the resin beads inside the softener tank through the backwash, charge, and rinse processes. However, Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant's current guidelines are lack information about the optimum amount of inlet pressure for each softener regeneration process and also the dosage of chemicals needed for the boiler water quality. The objective of this experiment is to perform the boiler's softener regeneration process with five different stages of inlet pressure. Next, analyses the results of the boiler water treatment test, i.e., sulphate, hydrate alkalinity, and pH value, using BP 100 and BP 210 chemicals to comply with the water quality guidelines from the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant. Water quality tests, i.e., total hardness, pH value, hydrate alkalinity, and boiler chemical addition, will be conducted in the biodiesel lab using the water quality test kit and apparatus. The results of the water quality test will be analyzed at the end of the experiment to determine whether they comply with the water quality guidelines. In this project, the optimum amount of inlet pressure for softener regeneration and the dosage of chemical required in boiler water were determined. In the future, this project can serve as a reference for the softener regeneration process guidelines using different types of resin beads, such as fine mesh resin and cross-link resin.

Keywords: Boiler Water Quality, Softener Regeneration Process, Scaling and Corrosion

1. Introduction

Hard water that comes from the domestic water supply tank contains unwanted ions like magnesium and calcium that can lead to the oxidation of metal to form a scale and corrosion inside the boiler tube and wall. Scaling and corrosion are common problems in boiler systems, which can result in inefficient

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boiler performance to generate steam while also reducing the boiler tube lifespan [1]. The quality of boiler feed water must comply with the guidelines that have been set by Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant to make sure that the ions contained in the water are safe to be used inside the boiler. The softener treatment process will eliminate those unwanted particles through an ion exchange process where the resin bead is used to attract the unwanted ions in hard water such as magnesium and calcium and replace them with sodium [2]. Normally, when two-thirds of the resin bed is frazzled, the resin beads will allow hardness to slip through. When this occurs, it is time to regenerate the resin beads through four different types of softener regeneration processes: backwash, charge, slow rinse, and fast rinse.

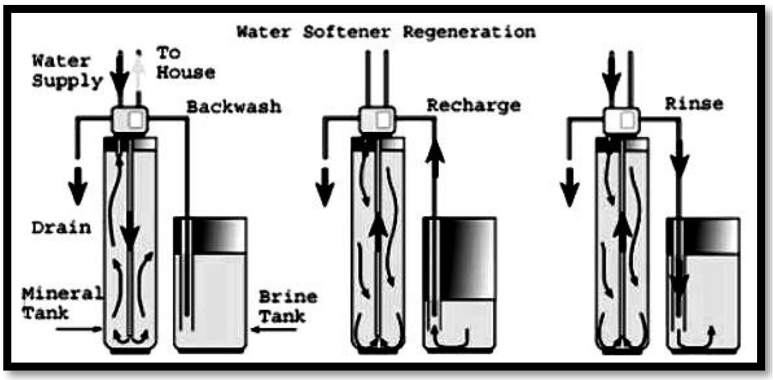

Figure 1 : The flow of water in softener regeneration process

The softener regeneration process required an optimum inlet pressure to enhance its capability of treating hard water. The backwash process required a much higher inlet pressure to lift and expand the resin beads inside the softener tank and prepare it for the next regeneration process [3]. The charge and slow rinse process required a much lower inlet pressure to ensure the process of ion exchange was successful while also flushing out the remaining calcium and magnesium ions that were attached to the resin beads [4]. While the fast rinse process required an intermediate inlet pressure to flush out the brine solution and push the resin beads to the bottom of the softener tank [5].

Chemicals are widely used in boiler water treatment for controlling certain variables and parameters, i.e., the amount of sulphate, hydrate alkalinity, and pH value. BP 100 chemicals have been used to increase the sulphate value in boiler water and function as an oxygen scavenger in the water to prevent corrosion problems from occurring [6]. Next, BP 210 chemicals have been used to increase the pH value and hydrate alkalinity in boiler water to ensure the properties of the water are alkaline because acidic water can cause corrosion and scaling from inside the boiler. Hydrating the alkalinity of boiler water is essential to maintaining the alkalinity level when phosphate has been used in the boiler water to form softer, more easily removable deposits [7].

2. Materials and Methods

The main objectives of this project are to perform the boiler's softener regeneration process with five different stages of inlet pressure while also analyzing the boiler water treatment test, i.e., sulphate, hydrate alkalinity, and pH value using BP 100 and BP 210 chemicals. For this experiment, as shown in Figure 2, five different stages of inlet pressure, from 2.0 psi to 72.0 psi, will be regulated using a manual hand valve. Meanwhile, the softener handle will be the throttle for selecting the softener regeneration mode, i.e., backwash, charge, slow rinse, and fast rinse. Chemical additions to boiler water for BP 100 and BP 210 will be added to the boiler chemical tank according to the guideline.

Figure 2 : Manual hand valve, pressure gauge and softener handle

2.1 Materials

According to Figure 3, the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant uses a demineralization-type softener with a maximum operating pressure of 150 psi. The resin bead capacity inside the softener tank is 26 inches from the bottom. In biodiesel plants, a fire-tube boiler with three passes of reverse flame has also been used. The manufacturer of the boiler is MechMar Boilers Sdn Bhd, with approval from the Department of Occupational Safety and Health (OSHA). This experiment's materials and properties are detailed below:

The water softener tanks have been made of fiberglass-reinforced plastic.

i. Boilers have been made of alloy steel.
ii. Water quality test kit, i.e., sulphate, total hardness, hydrate alkalinity and pH value.
iii. Food-grade salt for the preparation of brine solutions.
iv. BP 100 and BP 210 chemicals.

Figure 3 : Softener equipment for treating hard water

2.2 Methods

The flowchart is very important as a diagram that shows the workflow of the experiment. These experiments are conducted at the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant. The data results are analysed and included in the project report. The results of the water quality test have been compared to the current guidelines by the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant. Figure 4 shows the study flowchart for completing this study.

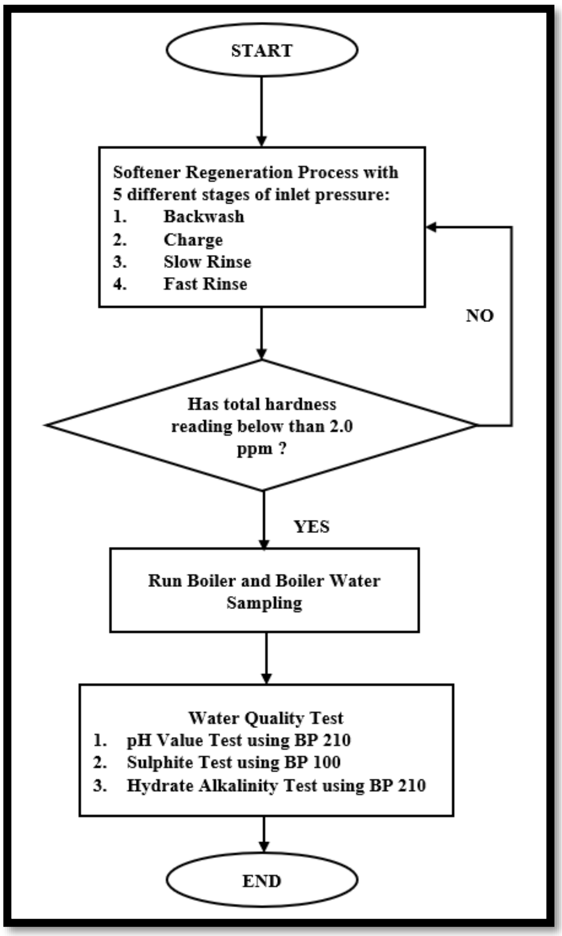

Figure 4 : Methodology flowchart for the experiment

2.3 Equations

The following formula was used when conducting the water quality test. Equation 1 is used to calculate the total hardness. Equation 2 for calculating the amount of sulphate. Equation 3 is used to calculate total alkalinity. Equation 4 is used to calculate the hydrate alkalinity. Every drop of chemical must be counted and recorded to be used in this formula.

$$\text{Total hardness (ppm)} = \frac{\text{Drops of EDTA}}{\text{Drops per ml}} \times 20 \qquad \text{Eq. 1}$$

$$\text{Sulphate (ppm)} = \frac{\text{Drops of P.I}}{\text{Drops per ml}} \times K \qquad \text{Eq. 2}$$

$$\text{Total Alkalinity (ppm)} = \frac{\text{Drops of sulfuric acid}}{\text{Drops per ml}} \times 40 \qquad \text{Eq. 3}$$

$$\text{Hydrate Alkalinity (ppm)} = \frac{\text{Drops of sulfuric acid}}{\text{Drop per ml}} \times 4 \qquad \text{Eq. 4}$$

3. Results and Discussion

The results covered the experimental and analytical aspects of boiler water treatment through softener regeneration processes. The result obtained must comply with the water quality guidelines established by the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant.

3.1 The optimum inlet pressure for backwash process

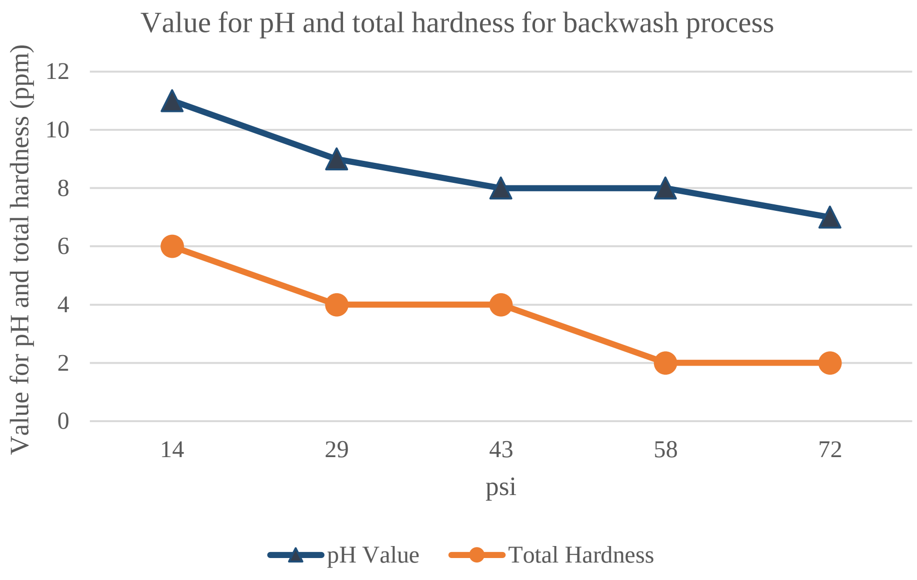

Figure 5 : Water quality chart for backwash process

According to the chart in figure 5, both the pH value and the total hardness reading have exhibited a decreasing trend. The pH value indicates whether the softener water is acidic or in an alkaline state, and the recommended limit for the pH value of softener water is between 7 and 8. Meanwhile, at 58.0 psi, recorded data shows the best reading for the pH value at 8 and the total hardness value at 2.0 ppm during the backwash process, which comply with the water quality guideline.

3.2 The optimum inlet pressure for charge process

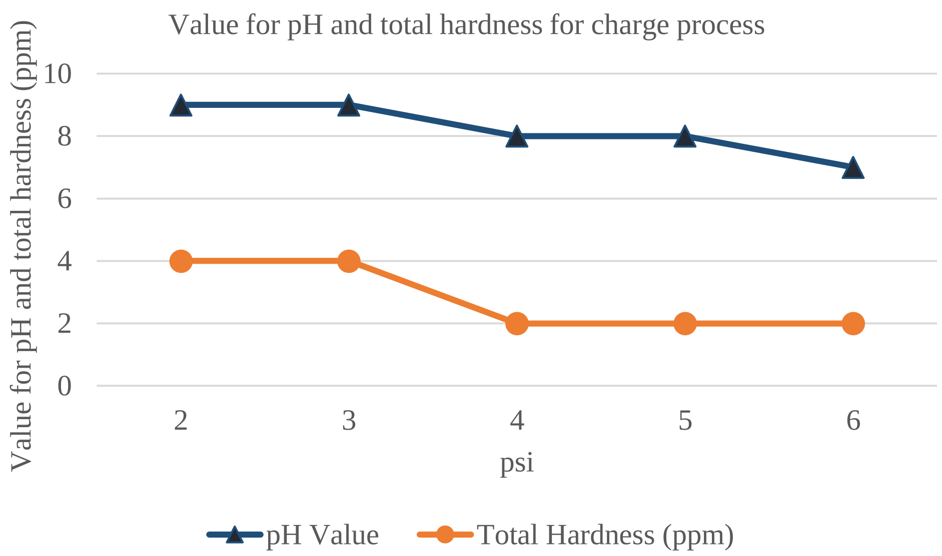

Figure 6 : Water quality chart for charge process

According to the chart in figure 6, the charge process requires a much lower inlet pressure, between 2.0 psi and 6.0 psi, to ensure the success of the ion exchange process. Both the pH value and the total hardness reading have exhibited a decreasing trend. According to the chart, recorded data shows the optimum inlet pressure is at 4.0 psi for the charging process. At 4.0 psi, the result shows a PH value of 8 and the total hardness value of 2.0 ppm during the charging process, which comply with the water quality guideline.

3.3 The optimum inlet pressure for slow rinse process

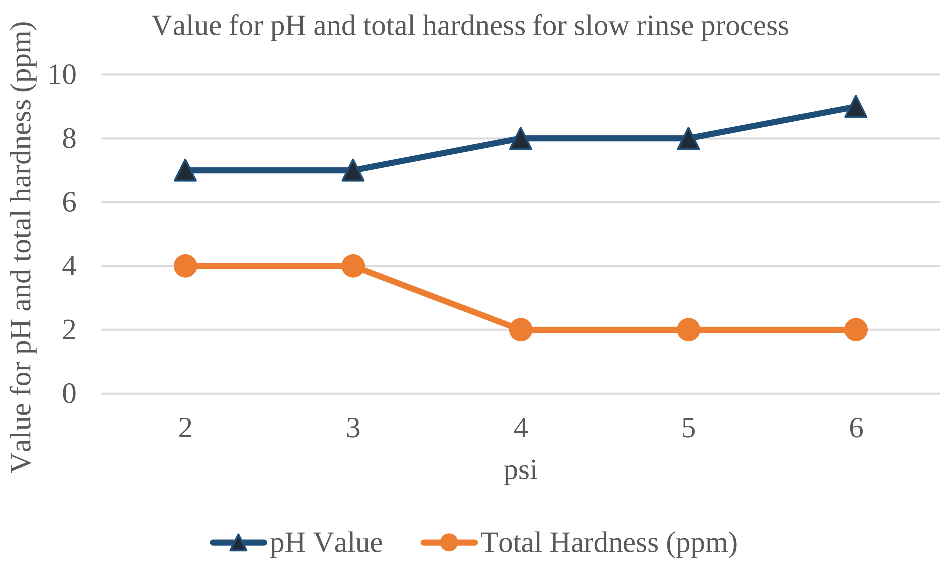

Figure 7 : Water quality chart for slow rinse process

According to the chart in figure 7, when the amount of inlet pressure is increased, the trend in increasing forms has been recorded for the reading of the Ph value. Meanwhile, the trend of total hardness readings decreases when the amount of inlet pressure is increased. According to the chart, recorded data shows the optimum inlet pressure is at 5.0 psi for the slow rinse process. At 5.0 psi, the result shows a PH value of 8 and the total hardness value of 2.0 ppm during the slow rinse process, which comply with the water quality guideline.

3.4 The optimum inlet pressure for fast rinse process

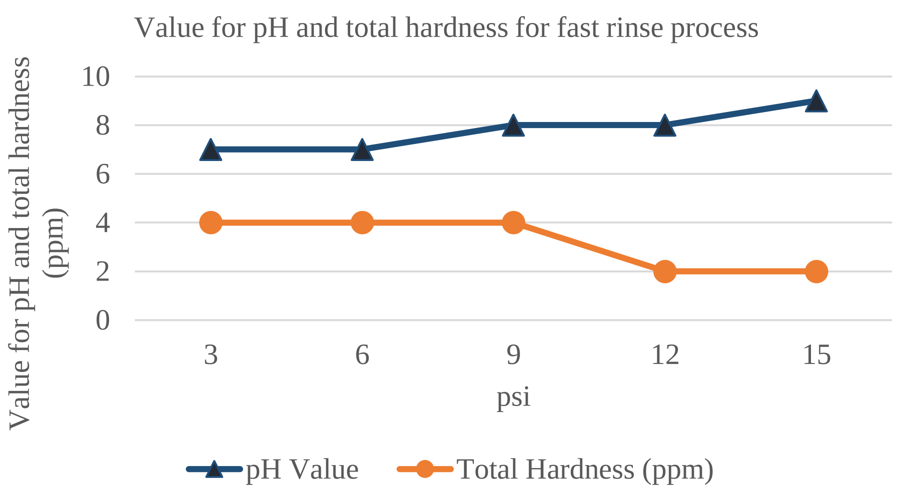

Figure 8 : Water quality chart for fast rinse process

According to the chart in figure 8, when the amount of inlet pressure is increased, the trend in increasing forms has been recorded for the reading of the Ph value. Meanwhile, the trend of total hardness readings decreases when the amount of inlet pressure is increased. According to the chart, recorded data shows the optimum inlet pressure is at 12.0 psi for the fast rinse process. At 12.0 psi, the result shows a PH value of 8 and the total hardness value of 2.0 ppm during the fast rinse process, which comply with the water quality guidelines.

3.5 Tables of water quality data for softener regeneration process

According to Table 1, there are four processes involved in the softener regeneration process. After completing the experiment, students must determine the optimum amount of inlet pressure that complies with the guideline for pH value and the total hardness of boiler water quality.

Table 1: Water quality data for softener regeneration process

Process	Duration (min)	Inlet pressure (psi)	Parameter for pH and total hardness
Backwash	10	58.0	8.0 and 2.0 ppm
Charge	20	4.0	8.0 and 2.0 ppm
Slow Rinse	15	5.0	8.0 and 2.0 ppm
Fast Rinse	20	12.0	8.0 and 2.0 ppm

Table 1 shows the water quality data for the softener regeneration process. After completing the experiment, the students discovered that 58.0 psi was the optimum inlet pressure to lift and expand the resin beads in the backwash process. Next, the optimum inlet pressure for the charge process is 4.0 psi to slowly draw the brine solution into the softener tank. The slow rinse process is best at 5.0 psi to flush out the remaining hardness that is still attached to the resin beads. Lastly, the fast rinse process required an inlet pressure of 12.0 psi to drain out the remaining brine solution inside the softener tank and push the resin beads to the bottom of the softener tank. The value for pH is constantly at 8.0, and total hardness is also constantly at 2.0 ppm.

3.6 Recommended optimum inlet pressure chart for softener regeneration process

The values of pH and total hardness for the softener regeneration process were taken based on four optimum inlet pressures that have been determined for each of the processes. Figure 9 shows the chart for the optimum inlet pressure in the softener regeneration process.

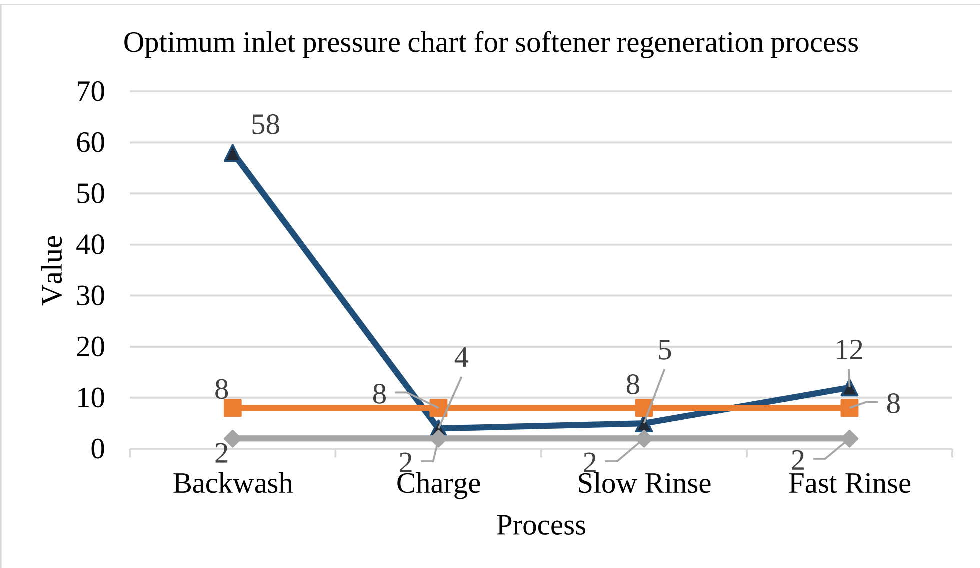

Figure 9 : Optimum inlet pressure chart for softener regeneration process

3.7 Dosage of chemical needed for boiler water treatment

The dosage of chemicals needed for boiler water treatment has been identified for stabilizing the amount of sulphate, pH value, and hydrate alkalinity in the boiler water. Before the experiment began, the sample of boiler water had a pH value of 9.0, 16 ppm of sulfate, and 65 ppm of hydrate alkalinity. Figure 10 shows the recorded data for the sample of boiler water before the experiment began.

Variable measured	Recorded data before	Parameter control limit
Ph Value	9.0	10.0 – 12
Hydrate Alkalinity	65 ppm	100 – 450 ppm
Sulphate	16 ppm	20 – 50 ppm

Figure 10 : Recorded data for the sample of boiler water before the experiment

According to Table 2, the chemical dosage for stabilising the boiler water has been identified. By adding 1.0 kg of BP 100, the sulphate reading has increased from 16 ppm to 35 ppm, which is in compliance with the water quality guideline set by the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant. Meanwhile, after adding 3.0 kg of BP 210 chemical, the pH value also increased from 9.0 pH to 12 pH. Next, hydrate alkalinity also increased from 65 ppm to 274 ppm after BP 210 was added for 2.5 kg. Table 2 shows the recorded data for the sample of boiler water after the experiments have been done.

Table 2: Water quality data for dosage of chemical in boiler water treatment

Chemical	Parameter measured	Chemical dosage (kg)	Parameter recorded
BP 100	Sulphate (ppm)	1.0	35 ppm
BP 210	pH Value	3.0	pH 12
BP 210	Hydrate Alkalinity (ppm)	2.5	274 ppm

3.8 Chart for the value of sulphate using BP 100

The dosage of chemical addition for BP 100 into boiler water is 0.5 kg to 1.5 kg. This range for chemical addition is based on a suggestion from the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant head of operation and technical staff for controlling the amount of sulphate.

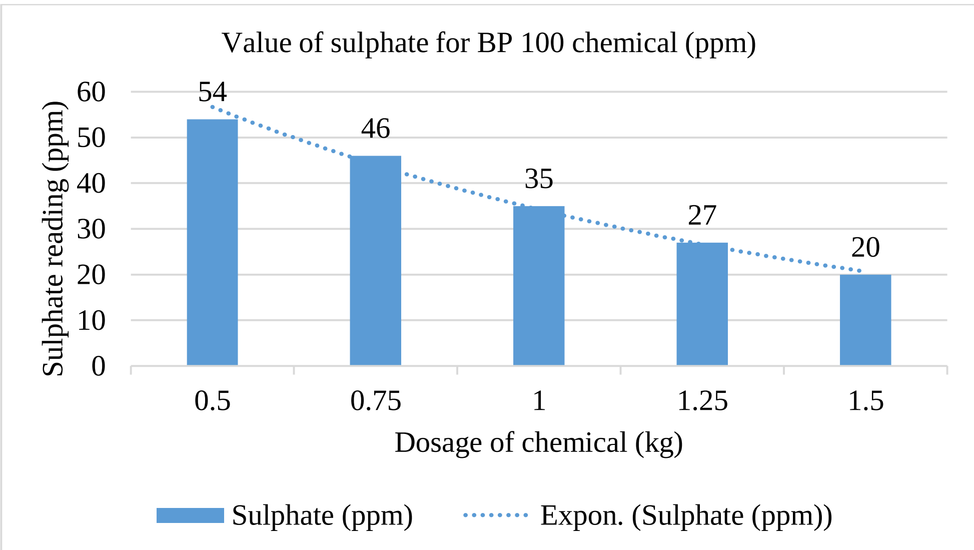

Figure 11 : Chart for the value of sulphate using BP 100

Figure 11 shows that the sulphate reading has been decreasing while the chemical dosage has been increasing. For boiler water and a 1.0 kg dose of BP 100, the recommended range for sulphate readings is 20-50 ppm. The best reading for sulphate has been obtained at 35 ppm. Sulfate is important for boiler water to scavenge oxygen inside the water so that corrosion problems will not occur.

3.9 Chart for the value of pH using BP 210

The dosage of chemical addition for BP 210 into boiler water is from 1.0 kg to 3.0 kg. This range for chemical addition is based on a suggestion from the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant head of operation and technical staff for controlling the amount of potential hydrogen.

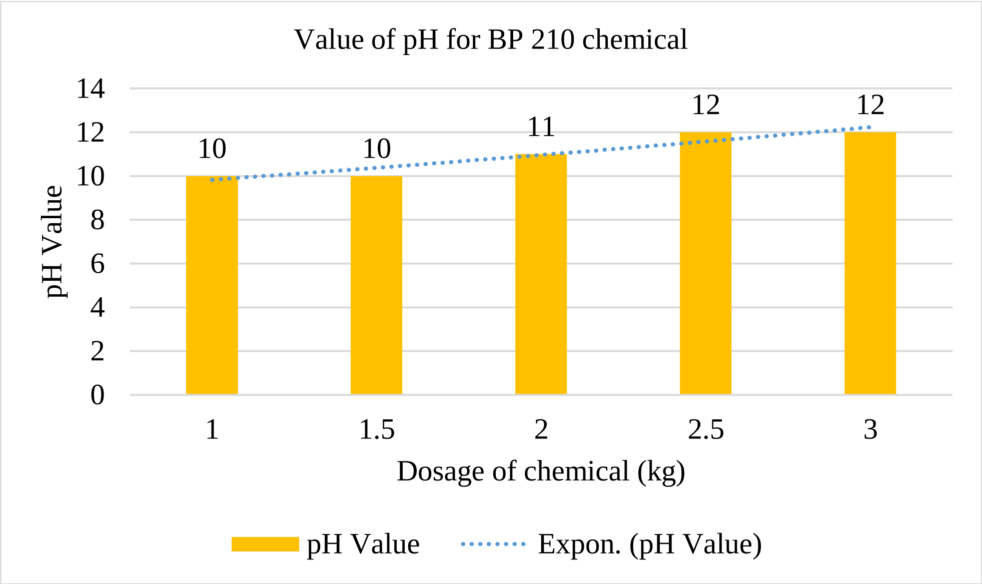

Figure 12 : Chart for the value of pH using BP 210

According to Figure 12, an increased trend in pH readings has been recorded while the dosage of chemicals has increased. At 3.0 kg, the best reading for pH has been obtained at 12 pH. The importance of having a suitable pH value for boiler water is crucial to making sure the water that has been used in the boiler is alkaline because acidic water can cause corrosion and scaling from inside the boiler.3.10 Chart for the value of hydrate alkalinity using BP 210

The dosage of chemical addition for BP 210 into boiler water is from 1.0 kg to 3.0 kg. This range for chemical addition is based on a suggestion from the Universiti Tun Hussein Onn Malaysia (UTHM) Biodiesel Plant head of operation and technical staff for controlling the amount of hydrate alkalinity.

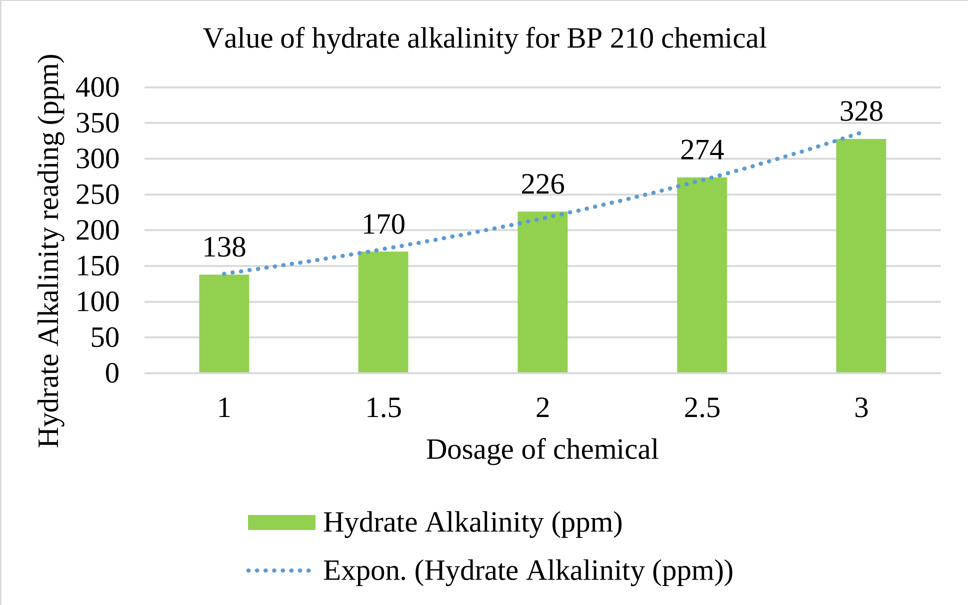

Figure 13 : Chart for hydrate alkalinity using BP 210

According to Figure 13, an increased trend in hydrate alkalinity readings has been recorded while the dosage of chemicals has increased. At 2.5 kg, the best reading for hydrate alkalinity has been obtained at 274 ppm. The importance of having a suitable hydrate alkalinity reading for boiler water is essential to maintaining the alkalinity level when phosphate has been used in the boiler water to form softer, more easily removable deposits.

4. Conclusion

From the experiment, the objective to perform the boiler's softener regeneration process with five different stages of inlet pressure while also analyzing the boiler water treatment test, i.e., sulphate, hydrate alkalinity, and pH value using BP 100 and BP 210 chemicals, has been achieved. According to the experiment that has been done, softener and boiler water sampling must be done once a week to analyses the water quality, i.e., pH value, total hardness, sulfate, and hydrate alkalinity. As an example, the reading of pH value and total hardness will be different in two weeks because of the reaction from the water inside the boiler that has been heating up previously. In the future, different types of resin beads can be used to measure the performance of water treatment, such as polystyrene gel resin, fine mesh resin, and cross-link resin.

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