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Use of Gray Water in Cooling Air Conditioning Condenser

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Abstract
Arid and semi-arid countries experience challenges especially in the use of air conditioning units which tend to consume more electricity in the summer due to the effect of the heat on the compressor. The solution to this problem is the use of spray cooling with the spray targeting the compressor to cool it through evaporation as a result of the absorption of the latent heat of vaporization. However, a problem still exists in these countries mainly because they lack adequate water and have to resort to the use of gray water. This paper, therefore, investigates the use of gray water as a spray coolant and its effects on nozzles of various sizes.Gray water contains minerals and chemicals which are bound to accumulate at the tip of the nozzle in a process called scaling. Scaling results in the narrowing of the nozzle affecting the spread diameter, nozzle diameter and the cone angle of the resultant spray. The experiment highlighted in this paper will use tap water and gray water both of which are tested using two nozzles. The diameter of the nozzles is measured with the utilization of a microscope while the cone angle of the resultant spray is measured with the use of images taken from a high-resolution camera.It is observed that both tap water and gray water produce a certain amount of scaling at the tip of the nozzles. The scaling affects the cone angles and the spread diameters. While tap water has a small reduction in the cone angle, the gray water results in a larger reduction. The tap water also results in an increase in the effective spread diameter while the gray water results in its decrease. However, because water is scarce in the arid countries, gray water is the most suitable with the solution to the problem being the constant replacement of the nozzles after a particular period.

I. Introduction

1.1 Wastewater reuse

In a semi-arid and arid country such as Saudi Arabia, sustainable management of water is very crucial for socioeconomic development to be achieved. In fact, the comfort living of people in arid and semi-arid regions directly depends on effective water conservation and water reuse practices. Although large-scale wastewater reuse measures have been adopted such as use of treated municipal effluent to irrigate golf courses, gray water recycling is an important option that people can use to save wastewater in homes.

1.2 Gray water reuse

Gray water generally refers to the domestic untreated wastewater that has not been polluted by the toilet waste. Usually, it includes all the water that drains from the showers, laundry tubs, bathtubs, hand basins, washing machines, and floor wastes (World Health Organization, 2006). However, it excludes the wastes from dishwashers, garbage disposal units, and kitchen sinks. Since graywater does not contain fecal coliform or organic matter, it can be treated much easily than the black water from toilet and kitchens. According to a report by World Health Organization (2006), graywater constitutes 61% of the total wastewater generated by households. Certainly, if the gray water is managed responsibly without posing a threat to human health, it can significantly contribute to the sustainability of water resources. The reuse of gray water ensures that the load on wastewater treatment systems is decreased and therefore, the authorities save money spent on treatment of sewage. Besides, the lifespan of the wastewater treatment systems are prolonged and the demand of potable water by the public is reduced.

Generally, graywater can be reused in different areas such as landscaping, toilet flushing, car washing, garden watering, irrigation, and cooling purposes in industrial plants (World Health Organization, 2006).

The reuse of gray water in cooling has gained special attention recently with a several power plants in freshwater constraint areas adopting graywater in their recirculating water cooling systems. The primary challenges encountered when using gray water as a coolant is that it contains significant amounts of hardness, ammonia, phosphate, organic matter, and dissolved solids in comparison to fresh water (Li, Jason, Vidic, & Dzombak, 2011). The elevated quantities of these minerals coupled with high temperatures normally cause mineral deposition problems (scaling) both in the spray nozzle and on the surface being cooled.

In the meantime, air conditioning (AC) systems account for nearly 50% of power consumption in the Kingdom. In the residential sector alone, it is estimated that 70% of power consumption is due to AC systems. The problem is more serious in the summer, because the performance of air-cooled AC systems, such as window type and split case units, deteriorates considerably when the ambient air is hot. The reason is that heat needs to be rejected from the condenser of the AC system to the ambient air at extremely high temperatures and pressures, making the power consumption of the compressor very high. One way to improve the performance of an air-cooled AC system is to create a cool environment around the condenser such that the temperature of heat rejection is reduced, thereby reducing the power consumption of the compressor. This can be done by attaching an evaporative cooling system to the condenser of the air conditioner. Figure 1 shows an example of such a system.

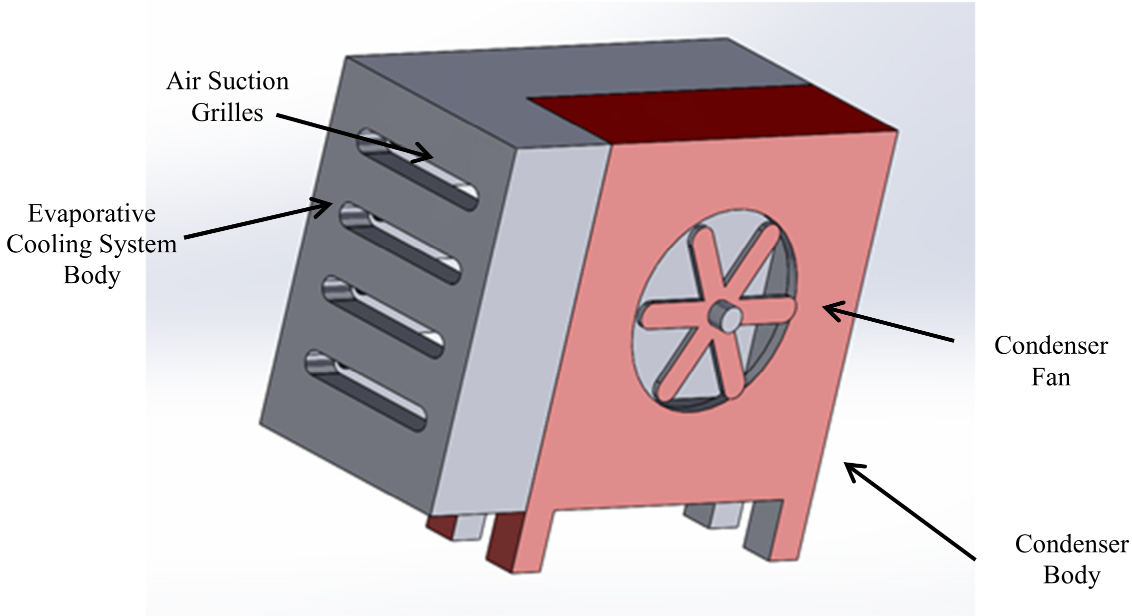

***Figure 1**: Sketch of evaporative cooling system surrounding the condenser of an air conditioner*

Depending on ambient conditions, the type of evaporative cooling system used, and the amount of water injected, a significant reduction in power consumption can be realized.

Certainly, adoption of gray water as an evaporative cooling medium for air conditioning can ensure that significant amounts of potable water are saved (Hou, 2014). The use of gray water in air conditioning also ensures that more businesses and homes in arid areas are more efficiently and effectively cooled (Heng 2011).

In particular, mosques are a great candidate for use of gray water for air conditioning. The main reason is that gray water effluent from mosques contains minimal pollutants since it is mostly the result of ablution. Therefore, the treatment needed can be simple filtration and minimal chlorination. Another reason is that the cooling load in mosques is huge due to their large sizes, making them a high priority for the use of evaporative cooling for air conditioning.

For the reasons above, this study will focus on the use of gray water effluent from mosques to cool the condensers of air conditioners evaporative.

1.3 Research Objectives

a. To analyze gray water composition of an office building in Riyadh.
b. To measure scale formation on the tip of a spray nozzle when gray water is used.
c. To measure cone angle and spread diameter of the nozzle when gray water is used.

II. Literature Review

2.1 Gray water use in Saudi Arabia

Due to the growing demand for water in the domestic, commercial, and industrial sectors in Saudi Arabia, the Ministry of Water and Electricity published a guide in 1429H explaining how gray water can replace potable-quality water in numerous applications, and how gray water systems should be installed. Al-Wabel (2011) described a simple system for handling and reuse of gray water resulting from ablution in mosques in Riyadh. He concluded that tertiary treatment quality water can be achieved by using sand filters, activated charcoal, and an ultraviolet unit. Abu-Rizaiza (2002) also suggested that gray water can be used for irrigation of public areas as well as for flushing toilets, and proposed the development of a plumbing system designed to collect, filter and disinfect ablution water to be used subsequently for other purposes.

2.2 Spray cooling

Essentially, spray cooling involves a liquid being forced from a small orifice and getting released as a dispersion of droplets which then impact on the surface to be cooled. According to a study by Grissom and Weirum (2012), there are three modes of operation in spray cooling. The first mode is that of a spray forming a thin liquid film on the surface of the material being cooled in what is commonly known as the flooded state. The droplets usually spread and then evaporate, retracting with them large quantities of energy due to latent heat of vaporization and creating a cooling effect. The second mode is that of the hot surface vaporizing all the impinging spray in a process called dry-wall state. The third mode is called Leiden frost state and involves the sprayed liquid forming an insulating vapor layer that prevents a material from heating rapidly (Jia & Qiu, 2013). The droplets may also puncture the entrapped vapor and thereby increase the rate of heat transfer. Spray cooling is normally preferred because cool liquid water gets much closer to the hot surface compared to other cooling methods such as pool boiling. However, its successful usage depends on numerous factors such as droplet velocity, droplet size distribution, the impact angle, gas content, droplet number density, and heater surface orientation. Besides, spray cooling is commonly used in electronic cooling, fire suppression, and coal gasification, and treatment of steel.

In a study of how suitable nanofluids could be used in spray cooling on copper blocks, Bansal and Pyrtle (2010) reported an enhanced heat transfer performance of the nanofluids compared to the pure fluids. Nanofluids are the fluids whose particles are less than 100 nm in size and are composed of particles of oxides, metals, carbides, and nitrides. Duursma et al (2013) noted that the fraction of a nanoparticle affects its spreading ratio, breakup, and the rebound of sprayed droplets which ultimately affected the heat transfer performance (Bellerova, Tseng, & Pohanka, 2012). A research by Tilton and Morgan (2012) revealed that the presence of non-condenser gas reduced the condenser performance and in fact, increased the surface temperature and the boiling temperature for fixed volume systems. They also established that dissolved gas increased the maximum heat transfer. Besides, Morgan and Tilton also realized that critical heat flux in spray cooling was due to liquid deficiency which was attributed by the droplet splashing, getting entrained, and nucleate bubbles explosion (Jia & Qiu, 2013). An experiment by Kiger and Kim (2011) showed that for temperatures slightly above or below the boiling temperature, the dissolved gas was noted to improve the heat transfer probably because of an increase in the circumference of the splat. Additionally, Kiger and Kim (2011) observed that when 1% weight of sodium hydrogen carbonate solution was added to water, it decayed into sodium carbonate and carbon dioxide when heated during cooling. The carbon dioxide produced caused the droplet to swell thereby increasing the size of contact area (Kim, Horacek, & Kiger, 2011). On the contrary, the precipitated sodium carbonate salt formed a nucleation site for scaling of particles.

In yet a different study on spray cooling, Chien et al (2009) noted an increase in the heat transfer performance when the liquid volume flow rate was increased. Their data also indicated that the performance of heat transfer depended on the surface enhancement ratio Additionally, a research conducted by Bostanci et al. (2010) on the effect of using ammonia in spray cooling of structured surface revealed that heat transfer increased by 49% and 112% for surfaces with indentations and protrusions respectively compared to smooth surfaces (Hou & Tao, 2014). Recently, a new study on spray cooling revealed that the critical heat flux (CHF) for a large area (19.3 sq. cm) was 34% lower compared to that of a small area (2 sq. cm) when an eight-nozzle water spray was use (Horacek & Kiger, 2010). The authors suggested that multiple nozzle spraying resulted in accumulation of water on heated surface and caused the lower heat transfer in large surfaces.

2.3 Scale Formation

Past research has shown that the thickness and rate of scale formation on the cooled surface depended on the surface temperature and water chemistry. It has also been found that scale forms more quickly on higher temperature surfaces. According to a study by Nalepa et al. (1999), a key concern when using gray water for cooling is the need to control bio growth. Their study revealed that the use of chlorine as a biocide compromises the effectiveness of graywater as a coolant since it enhances mild steel corrosion due to its nature as a strong oxidant (Li, Jason, Vidic, & Dzombak, 2011). A different study by Eriksson et al (2007) revealed four ways of inhibiting scale formation when using gray water as a spray coolant. Firstly, adsorption of antiscalants is to be done on the surface to be cooled so as to prevent deposition of minerals on that surface during cooling. Secondly, antiscalants can be applied to ensure the minerals particles are dispersed in the aqueous solution and therefore cannot be deposited to cause scaling. Thirdly, antiscalants can be applied in order to react with a newly formed mineral nuclei and interrupt the crystallization process which ultimately inhibits the growth of precipitating particles (Li, Jason, Vidic, & Dzombak, 2011). The fourth mechanism for inhibiting scale formation is by adding antiscalants so as to increase the solubility of calcium and magnesium cations that often cause scaling. According to Metcalf and Eddy (2007), prior to use gray water for cooling or other purposes, it should be filtered through a 0.45μm sieve, and then evaporated at 40 degrees Celsius to reduce hardness caused by magnesium and calcium cations.

III. Methodology

a. Method of Work

1. Several samples of gray water from an office building in Riyadh will be collected over the period of a few weeks. The samples will be analyzed to understand the properties of gray water. Based on the analysis results, a suitable treatment method will be implemented.

2. An experimental apparatus will be set up in order to run a long term test on a spray nozzle that uses the treated gray water. The purpose of the experimental campaign is to study scale formation with and without gray water. The experimental procedure is as follows:

a. Examine the tip of a new spray nozzle under the microscope to ensure that it is free of any scaling.
b. Spray regular tap water for 5-6 hours per day, for 2-3 weeks.
c. Re-examine the tip of the nozzle to characterize scale formation by looking at the average height of scale-crusts.
d. Examine the tip of another new spray nozzle under the microscope (as in Step a)
e. Spray treated gray water for 5-6 hours per day, for 2-3 weeks.
f. Re-examine the tip of the nozzle to characterize scale formation with treated gray water.
g. Compare scale formation in the two cases.

3. Another set up will be used to measure the cone angle and diameter of coverage of the spray with and without treated gray water. The objective of this experiment is to determine whether the use of treated gray water (with the potentially excessive scale formation) causes nozzle tip to be partially blocked such that the nozzle's performance will deteriorate with time as evidenced by the cone angle and diameter of coverage. The simple experimental setup will consist of a camera to measure the cone angle and hydrophilic paper to measure the spray diameter. The experimental procedure will be run in parallel to the experiment described in Part 2, and will consist of the following steps:

a. On each day of the experiment in Part 2, photos of the cone leaving the nozzle tip will be taken.
b. The photos will be studied to measure the cone angle.
c. At the same time, the hydrophilic paper will be placed at a fixed distance from the nozzle tip such that the water droplets wet it.
d. The cone diameter is measured and recorded.

(Fig. 2a)

(Fig. 2b)

Fig. 2a and 2b : *the set up for the system as used in the experiment*

b. Materials

1. High-resolution camera
2. Reservoir
3. Spray nozzle
4. Flowmeter
5. Pump
6. Treated gray water & tap water.

b. Description of Materials

1. Flowrate: 0.3 Liters per minute (LPM)
2. Pump Pressure: 100 psi
3. The number of nozzles that were studied: 2 nozzles in case of tap water, and two nozzles in case of greywater.
4. Hydrophilic paper distance from the nozzle tip = 25 cm

IV. Results and Discussion

4.1 Part 1: Analysis of gray water composition

A sample of gray water was collected from an office building in Riyadh over a period of a few weeks. This sample was then analyzed to help understand the properties of the gray water by studying its composition. Following the analysis, a suitable water treatment method was then implemented. The results of this study are tabulated in the table below and compared to the standards of the Ministry of Water and Electricity of Saudi Arabia.

Table 1: summary of the chemical composition of the Gray water used.

#	Measured Parameters		Result	Unit	Specifications	Method
1	**Hydrogen value**	pH	**6.95**	…….	6 – 8.4	SMWW-4500 H^+ B
2	**Total Dissolved Solids**	TDS	**1250**	mg/L	---	SMWW-2540 C
3	**Ammonia**	NH_3	**0.01**	mg/L	5	SMWW-4500 NH_3
4	**Chemical Oxygen Demand**	COD	**87**	mg/L	50	SMWW-5220 B
5	**Total Suspended Solids**	TSS	**4**	mg/L	10	SMWW-2540 D
6	**Total Organic Carbon**	TOC	**26.6**	mg/L	40	SMWW-5310 B
7	**Oil & Grease**	O&G	**ND**	mg/L	ND	SMWW-5520
8	**Free Chlorine**	Cl2	**1.13**	mg/l	0.2:0.5	SMWW-4500Cl F
9	**Nitrate**	NO3	**5.4**	mg/l	10	SMWW-4500 NO_3
10	**Fecal Coliform**	F. Coli	**0**	MPN/100ml	2.2/100ml	SMWW-9222
11	**Biological Oxygen Demand**	BOD	**2**	Mg/l	10	SMWW-5210 B

ND stands for not detected ،

The results were well within the range specified by the ministry. However, the quantity of particular parameters including chemical oxygen demand and free chlorine exceeded the set specification. The figure for the former stood at 87 against a specification of 50 mg/l while that of the latter stood at 1.13 against a specification that ranges between 0.2 and 0.5 mg/l. Additionally, due to the fact that gray water is not usually contaminated with toilet water, the sample did not contain fecal coliform. Also, the total dissolved solids do not have a ministry specification. The sample contained 1250 mg/l of total dissolved solids. The amount of free chlorine exceeded the specification because gray water is treated using chlorine. Finally, The sample contained 2 mg/l of biological oxygen demand against a specification of 10 mg/l.

4.2 Scale formation and diameter measurement

4.2.1 Tap water

Figures 3a and 3b represent the nozzles #1 and #2 respectively. The images viewed under a microscope showed the diameter of the two nozzles before the spraying of tap water was done. The diameter was found to be 336.75 µm for nozzle #1 while that for the nozzle #2 was found to be 480.83 µm. After the spraying had been done for 50 hours, precipitation was seen at the end of the nozzles as shown in Figures 4a, 4b, and 4c. This precipitation represented scaling which is caused by the growth of minerals present in the water. It varied in thickness for either nozzle. It ranged between 34.85 µm and 38.97 µm in nozzle #1 and 100 to 130 µm in nozzle #2. As such, the scaling is larger in thickness in the nozzle with the larger diameter than the nozzle with a smaller diameter (nozzle #1)

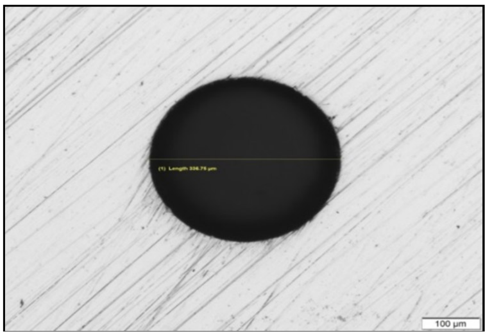

Fig. 3a: *the diameter of Nozzle #1 before spraying with tap water.*

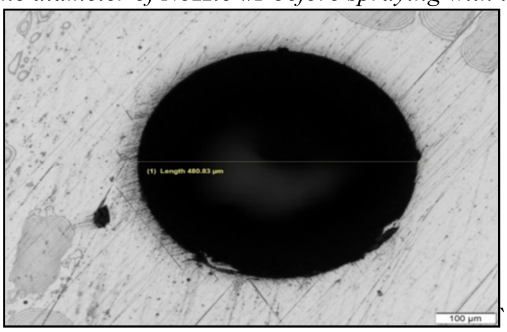

Fig. 3b: *the diameter of Nozzle #2 before spraying with tap water.*

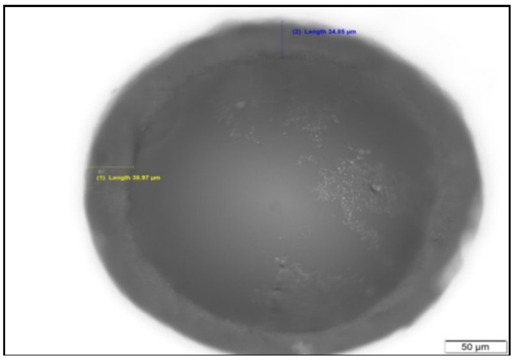

Fig. 4a: *the precipitation thickness of Nozzle #1 after 50 hours of spraying with tap water.*

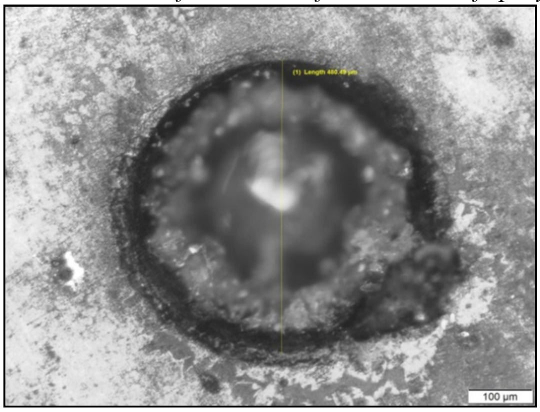

Fig. 4b: *precipitation thickness of Nozzle #2 after 50 hours of spraying with tap water.*

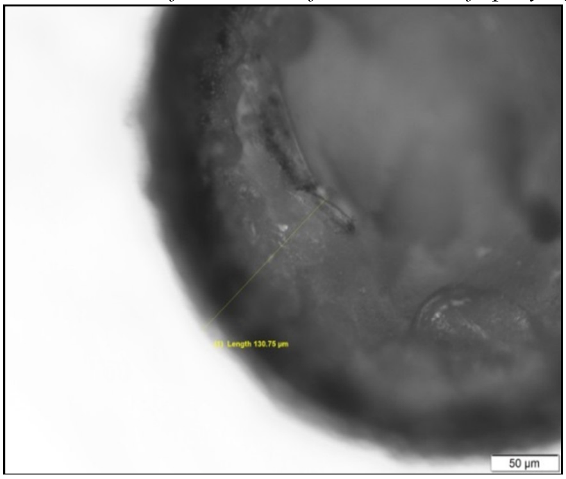

Fig. 4c: *Enhanced image showing precipitation thickness of nozzle #2 after 50 hours of spraying with tap water.*

4.2.1.2 Measurements using gray water

The nozzles used in this case differed from those in the first experiment. The figures 5a and 5b show the microscopic images of nozzle #1 and #2 prior to spraying with gray water. The diameter was found to be 446.61µm for nozzle #1 while that for nozzle #2 was 467.83 µm. Following the spraying that lasted 50 hours, precipitation was seen in both nozzles. The scaling ranged between 35.1 and 40.47 µm in the nozzle #1 while it stood between 24.9 and 29.29 µm. As seen from the experiment, it was seen that the scaling in the larger nozzle was smaller in thickness than that in the smaller nozzle. This is due to the amount of excess chlorine that caused the erosion of precipitation on the tip of nozzle.

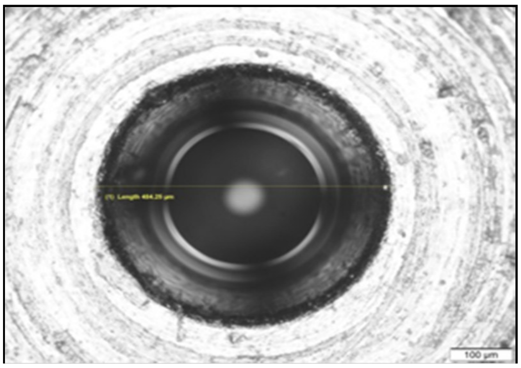

Fig. 5a: *the diameter of Nozzle #1 before spraying with gray water.*

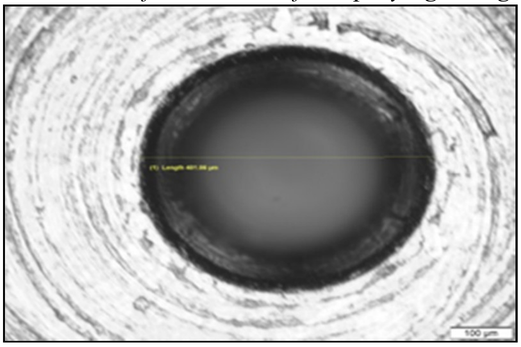

Fig. 5b: *the diameter of Nozzle #2 before spraying with gray water.*

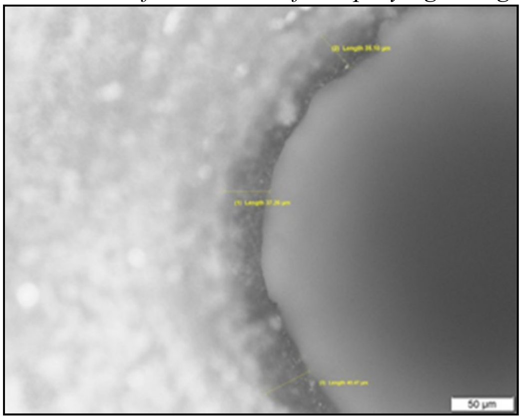

Fig. 6a: *the thickness of precipitation in Nozzle #1 after 50 hours of spraying with gray water.*

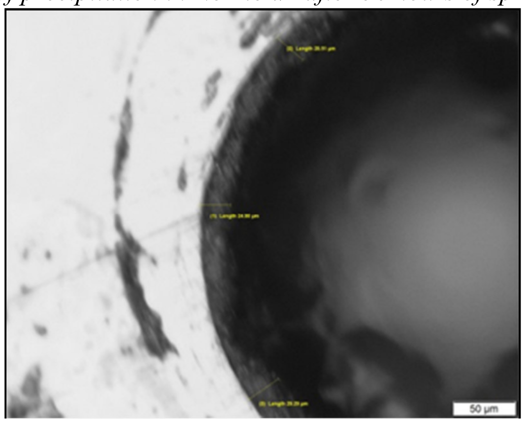

Fig 6b: *the thickness of precipitation in Nozzle #2 after 50 hours of spraying with gray water.*

4.3 Cone Angle and Spread diameter of the nozzle

Figures 7a and 7b represent the nozzle #1 and #2 showing the spray of tap water during the first hour of spraying. The cone angles were found to be 83.2° and 85.8° for nozzle #1 and #2 respectively. Following 50 hours of spraying, the cone angle was found to be 82.3° and 83.7° for nozzle #1 and #2 respectively. This represented a reduction in the angle for both cases. The decrease in nozzle #1 was 0.9° while that in nozzle #2 was found to be 2.1°. Evidently, angle difference in the nozzle #2 which had a larger diameter was larger than that in nozzle #1 which had a smaller diameter.

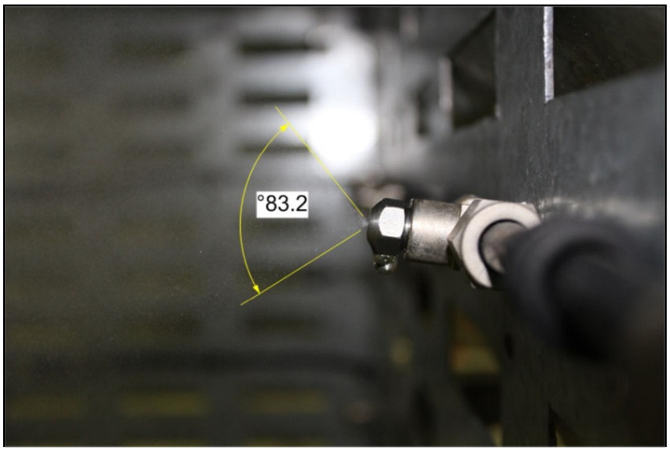

Fig. 7a: *the cone angle for nozzle #1 in the first hour of spraying with tap water*

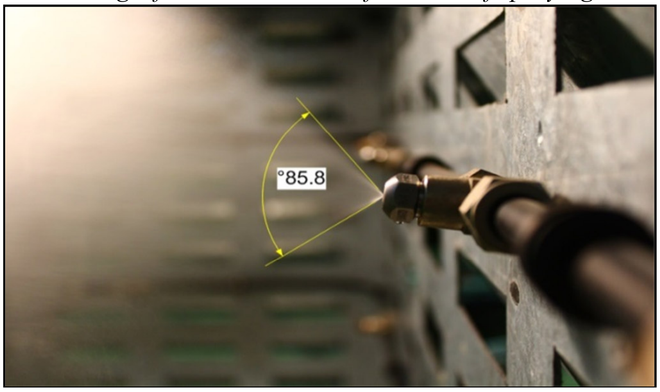

Fig. 7b: *the cone angle for nozzle #2 in the first hour of spraying with tap water.*

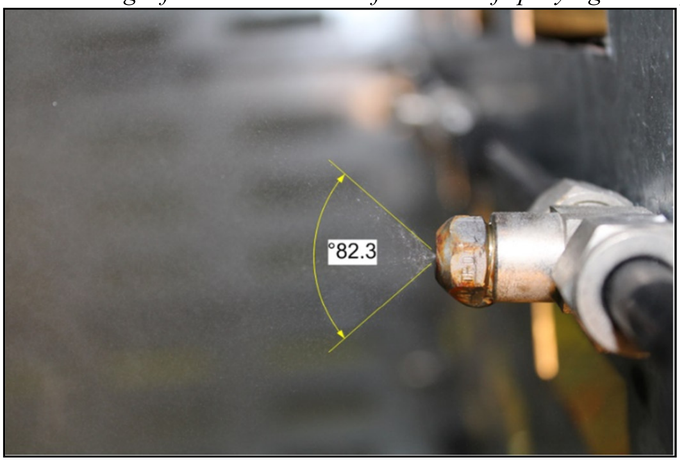

Fig. 8a: *the cone angle for nozzle #1 after 50 hours of spraying with tap water.*

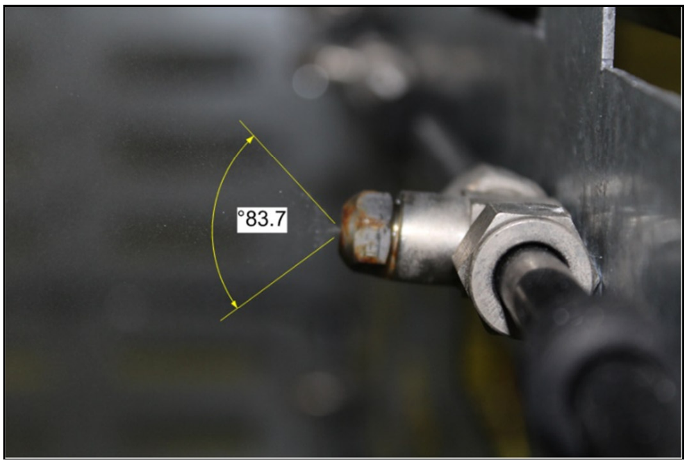

Fig. 8b: *the cone angle for nozzle #2 after 50 hours of spraying with tap water)*

Table 2: Summary of the cone angle, nozzle diameter and precipitation thickness when using tap water.

Tap Water Cone Angle and Diameter Measurement				
Nozzle #	**At 1st hour of Spray**	**At 50th hour of Spray**	**Diameter measurement**	**Formation thickness**
1	83.2°	82.3°	336.75 µm	34.85 - 38.97 µm
2	85.8°	83.7°	480.83 µm	100 - 130 µm

4.4 Cone angle when using gray water

Figures 9a and 9b represent the microscopic images of the spray emanating from nozzles #1 and #2 respectively in the first hour of spraying. The angles were found to be 81° and 86.6° respectively. Figures 10a and 10b, on the other hand, represent the cone angle of the spray after 50 hours of spraying. Due to the formation of the precipitation, the angle decreased to 77.6° in nozzle #1 and 83.4° in nozzle #2. This represented a reduction of 3.4° in nozzle #1 and 3.2° in nozzle #2. Evidently, the reduction when using spray water was more than when using tap water. Also, nozzle #1 had a greater difference than nozzle #2.

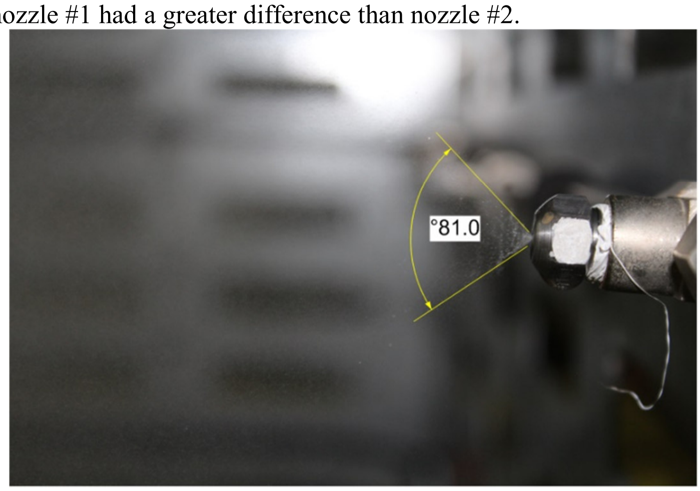

Fig. 9a: *the cone angle for nozzle #1 in the first hour of spraying gray water.*

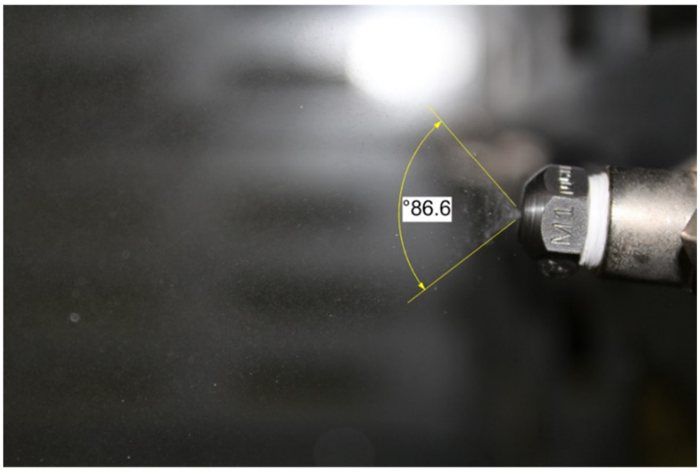

Fig. 9b: *the cone angle for nozzle #2 in the first hour of spraying gray water.*

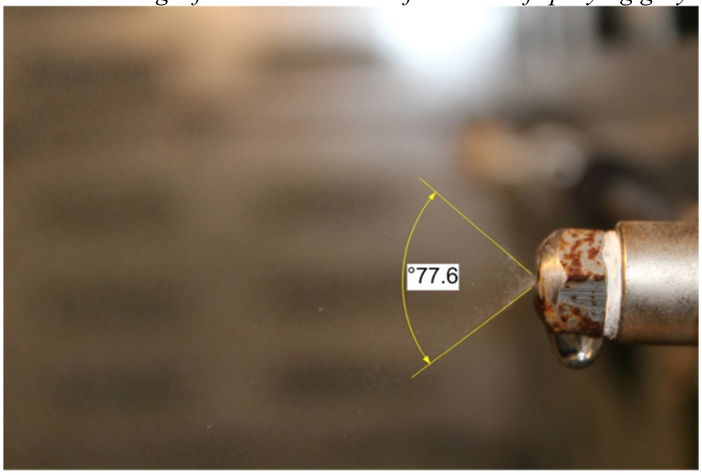

Fig. 10a: *the cone angle for nozzle #1 after 50 hours of spraying gray water.*

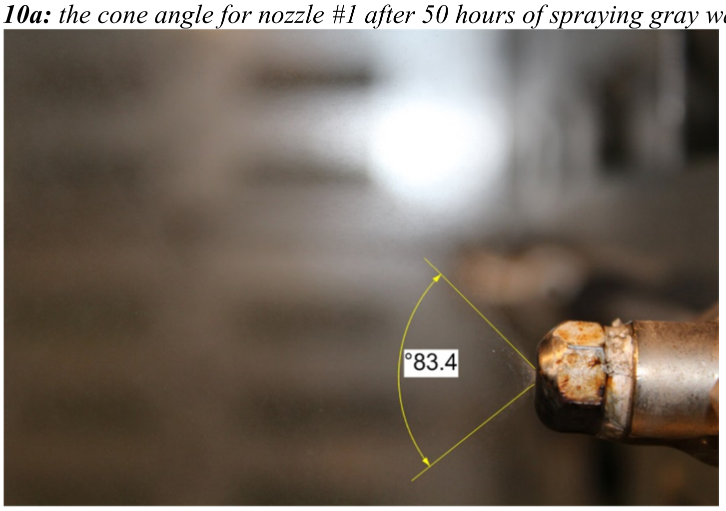

Fig. 10b: *the cone angle for nozzle #2 after 50 hours of spraying gray water.*

Table 3: summary of the cone angle, the nozzle diameter and the precipitation thickness when using gray water.

Grey Water Cone Angle and Diameter Measurement				
Nozzle #	**At 1st hour of Spray**	**At 50th hour of Spray**	**Diameter measurement**	**Formation thickness**
1	81°	77.6°	446.61 µm	35.1 - 40.47 µm
2	86.6°	83.4°	467.83 µm	24.9- 29.29 µm

4.5 Spread diameter

The spread diameter was measured with the use of the hydrophilic paper which was placed at distance of 25cm. It is a white paper which will stain representing the area that the spray will cover. The setup is represented in the following photo images.

Fig. 11: *various photographic angles of the hydrophilic paper set up.*

The data was represented in the following tables.

Table 4: Summarizing the area of tap water spread onto the hydrophilic paper.

Tap Water Spread Diameter		
Nozzle#	**At 1st hour of Spray**	**At 50th hour of Spray**
1	94.53 **cm²**	153.61 **cm²**
2	98.61 **cm²**	177.28 **cm²**

When using tap water, the area of spread increased significantly from the one recorded in the first hour and the value recorded after 50 hours of spraying. This applied for both nozzles. The spread diameter in the first hour of spray for nozzle #1 was 10.96cm while that for nozzle #2 was 11.21cm. After 50 hours of spraying, the spread diameter became 13.99cm for nozzle #1 and 15.02cm for nozzle #2. Clearly, the diameter increased and this can be attributed to the effect of the precipitation on the cone angle since by making it the opening of the nozzle narrower the resultant spray covered a larger area.

Table 5: Summary of the area of gray water spread on the hydrophilic paper

Grey Water Spread Diameter		
Nozzle#	**At 1st hour of Spray**	**At 50th hour of Spray**
1	201.17 **cm²**	160.14 **cm²**
2	162.27 **cm²**	160.5 **cm²**

The spread diameter, in this case, was smaller after 50 hours of spraying for both nozzles than it was in the first hour of spraying. The spread diameter in the first hour was 16.0cm for nozzle #1 and 14.37cm for nozzle #2. After 50 hours of spray the spread diameter was 14.28cm for nozzle #1 and 14.30cm. Evidently, while it increased in nozzle #1, it decreased in nozzle #2. This can also be attributed to the change in cone angle.

V. Conclusion

Arid and semi-arid countries face various challenges one of which is the high temperatures throughout the year coupled with the shortage of water. The situation is made worse during the summer when the temperatures are usually the highest recorded. At such times, air conditioning units are required. However, the high environmental temperatures affect the operations of the AC systems by hindering the functioning of the compressor. This part of the AC is usually responsible for absorbing the heat in the air thereby cooling the air. Nonetheless, during the summer, the high surrounding temperatures make it had for the compressor to lose the heat to the atmosphere.

A temperature gradient is required for there to be a loss of heat. To make this possible, the compressor consumes more energy in the form of electricity to help raise its temperature and therefore consequently create a gradient which promotes the loss. There is a solution to this problem which involves the use of spray cooling. In it, a nozzle that has a small diameter sprays water in the form of droplets which coat the surface of the compressor and bring about a loss in heat/ temperature through the evaporating water absorbing the latent heat of vaporization. The problem with this process is that the water scales the nozzle's tip reducing the diameter and the cone angle of the resultant spray. The purpose of this experiment was to investigate these changes and therefore ascertain whether gray water is suitable for use as the spray coolant.

The research found that indeed, there is a certain amount of scaling that occurs when either the tap water or the gray water is used. The thickness of the scaling depends on such factors as the diameter of the nozzle and the water itself. When tap water was used, the thickness of the scaling was found to have a larger thickness in the nozzle with the larger diameter whereas when the gray water was used, it was concluded that the scaling was significantly less in the nozzle with the larger diameter than in the one with the smaller diameter. Additionally, the difference in the cone angle was less when tap water was used than when gray water was used. However, the cone angle was still significantly large in the nozzle #2 even after scaling. When the two nozzles spraying gray water were compared, the angle difference was found to be less in nozzle #2 than nozzle #1.

In conclusion, it is clear that when gray water is used, the most suitable nozzle is the one with a larger diameter. This type of water is also preferred in arid countries which do not have an adequate supply of water.

Using gray water as a coolant will go a long way in reducing the electricity consumption in homes especially during summer as a result of the use of air conditioning units.

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