Experimental Design and Testing of Scale Development Reduction System in Domestic Water Geysers

Kabilan Sankar, Karthick Selvam, and K. Joy Ashwin

Abstract The aim of this project is to reduce the extent of scale formation in domestic water geysers with minimal investment that is efficient in cleaning and can be commercialized for consumer use. Modern water geysers have the disadvantage of a life of maximum of one year due to formation of scales on the heating coil and the walls of the geyser thereby reducing the efficiency of boiler and decreasing the life of geyser. The geyser is to be fitted with a 3D printed polymer float bounded by a soft brush. The variation in level of water inside the geyser will cause up and down movement of the float, brushing the internal wall of the geyser removing any salt presence. A nozzle system will be activated during the manual cleaning phase to provide a more efficient cleaning for the internal parts of the geyser and to wash away the salts from the brushes while drain them through a separate pipe. A valve system controls the direction of flow of fluid during the cleaning. The testing was done for a period of 240 days. The results showed a significant improvement in the performance of the geyser and reduced the extent of scale formation.

Keywords Domestic water geyser · Scale formation · 3D printed polymer float · Nozzle system · Valve system

1 Introduction

Scale formation occurs due to the presence of salts in water. Generally, water is classified into two types based on presence of salt. One type is hard water, and the other type is soft water. The main reason for scale formation in the water geyser is hard salts that present in the water. The presence of hard salt in water leads to clogging of the geyser outlet pipe and malfunction of electrical units due to leakage

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E. T. Akinlabi et al. (eds.), *Trends in Mechanical and Biomedical Design*,
Lecture Notes in Mechanical Engineering,
https://doi.org/10.1007/978-981-15-4488-0_3

of water leading to formation of scale formation of salt deposition and rust formation which in turns to corrosion. Scale formation also leads to gradual occurrence of pitting on the inner metal surface forming minute cracks or craters. McAdam and Parsons [1] performed experiments on calcium carbonate scale formation and control. Muryanto et al. [2] demonstrated the effects of calcium carbonate and salt deposits in clogging of pipes and major pipelines. Gal et al. [3] have performed experiments on calcium carbonate salt solubility in pipe clogging and their formation on the circumference of pipes. Kourtidou et al. [4] have worked on the impact of scale deposition in geysers and their connection to corrosion of metal. Tyler et al. [5] worked on experiments that studied the growth of scale deposition with increase in temperature. The scale formation in water geyser will reduce the life expectancy of the geyser and damages the electrical wiring in the form of leaks [6]. There are two types of hardness in water, temporary hardness and permanent hardness. Temporary hardness is a type of water hardness caused by the presence of dissolved bicarbonate minerals (calcium bicarbonate and magnesium bicarbonate). When dissolved, these minerals yield calcium and magnesium cations and carbonate and bicarbonate anions (CO_3^{2-}, HCO_3^-) [7]. Permanent hardness is hardness that cannot be removed by boiling. When this is the case, it is usually caused by the presence of calcium sulfate/calcium chloride and/or magnesium sulfate/magnesium chloride in the water, which do not precipitate out as the temperature increases. The presence of the metal cations makes the water hard [8] and increases the rate of salt deposition on the surface of the vessel in use [9, 10]. Hence, it will increase the maintenance cost and decrease the life expectancy of the geysers.

2 Methodology

Initially, two identical one-liter water geysers were selected for performing this experiment. Water geyser 1 did not have the scale reduction system installed inside, whereas water geyser 2 had the scale reduction system installed inside it. Water geyser 1 was used at a frequency of twice a day for a 240-day period. Water geyser 2 had its tank drilled at two locations, nozzles were installed on the walls of the geyser and the float is fitted inside the geyser. The float has some clearance between the geyser wall and itself which is filled by the brush. This brush bounds the float. The buoyancy force by the inlet water pushes the float up, brushing against the wall scrapping any salt presence. The cleaning phase was done once every month, thus totaling for eight times during this experiment. The properties of water such as hardness and salt deposits in it were periodically tested every month. The growth of scale development inside the geyser was also noted. Results were tabulated and plotted in the form of graphs.

3 Experiment Details

3.1 Construction

The water geyser tank was made up of stainless steel. The two side of the cylindrical tank was drilled for attaching nozzles. The nozzles were attached to the cylindrical wall, with the help of adhesives, to spray the water to the internal surface of tank to reduce the initial scale formation. The two valves are connected to the geyser system to control water flow as shown in Fig. 1. The one pair of valves was connected in the inlet to control inlet flow and another pair was connected in the outlet to control outlet flow. The ABS polymer float was placed inside the water geyser. The brush bounds the ABS polymer float to wipe out the scale formation vertically inside the geyser. The connecting pipes were used to connect the nozzle and valves to allow the fluid to the inlet flow. The gray water that is present inside the geyser after the

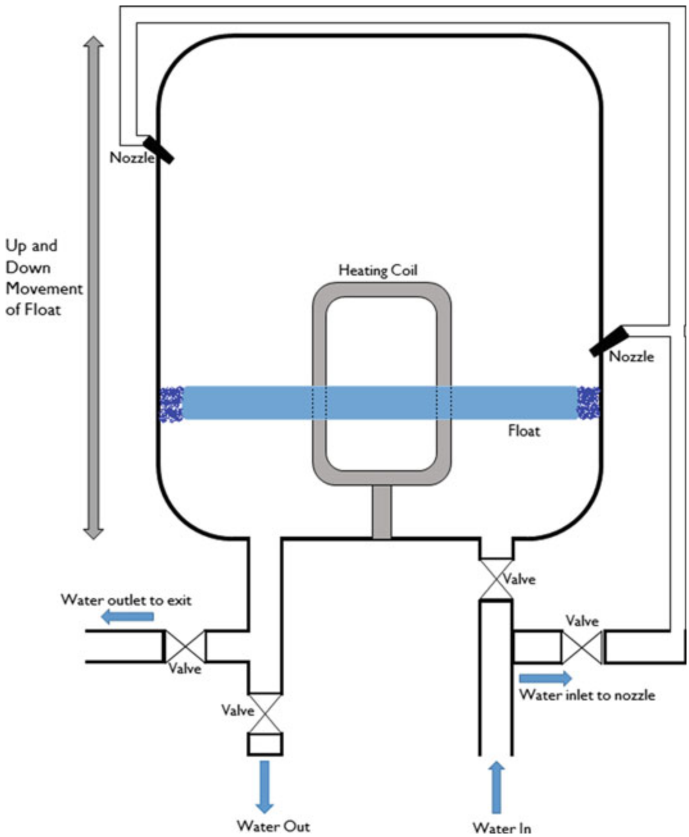

Fig. 1 Construction design of water geyser

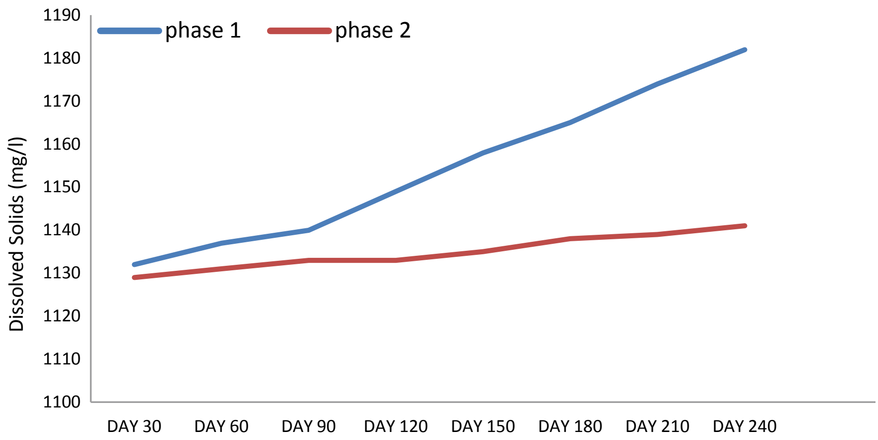

Fig. 2 Comparison of total dissolved solids in mg/l

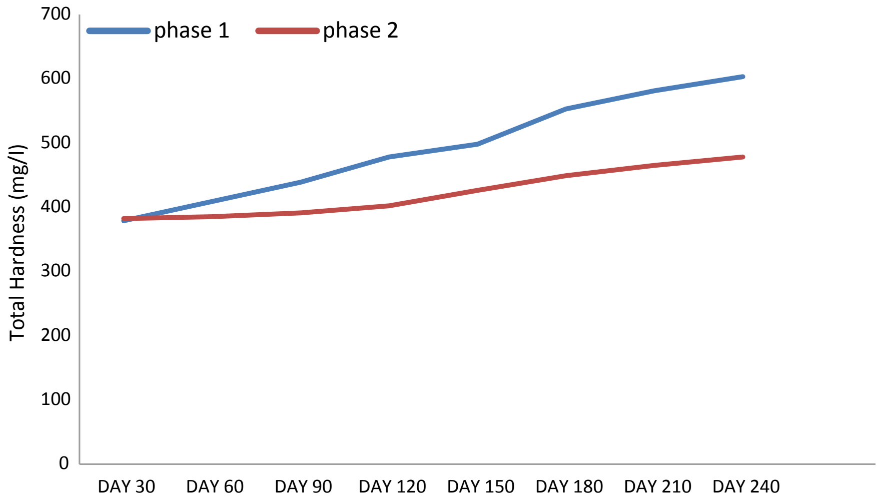

Fig. 3 Comparison of total hardness in mg/l

cleaning phase is exited through a separate outlet drain where the water is diverted using the valve system.

3.2 *Working*

The primary aim of the project is to study the formation of scales in the geyser and its effects on the efficiency of boiler, water output, and clogging of pipes. Testing of water was initiated to get the result for the two phases. Water from both the geysers were provided for testing at an external water testing laboratory in Chennai, India. The results of water hardness and dissolved solids were obtained directly from the laboratory upon submission of water samples. From the results of these two phases, we performed an analysis to compare both the set of results to find the conclusion.

Phase 1

The geyser was setup without our cleaning system to test the scale deposition rate and water quality for 34 weeks. The geyser was operated at a frequency of two times per day for 240 days where the water was heated to a temperature of 85 °C. The input water sample was tested initially. After a period of 240 days, we opened up the geyser to find out the thickness of scale deposited in the geyser. The rate of scale development was studied every month. The hardness and salt deposits value of the water were also noted. The results were tabulated.

Phase 2

Now, the geyser was setup with our cleaning system, and the same frequency of operation was continued for a period of 34 weeks. The cleaning was done once per month. The geyser operated well for 240 days heating water to a maximum temperature of 85 °C. The rate of scale development was studied every month. The hardness and salt deposits value of the water were also noted. The results were tabulated.

4 Results

4.1 Sample Collection and Testing

The output of the experiment is based on three parameters, total dissolved salts, total hardness content, and scale formation layer. Our aim is to reduce the value of these parameters by implementing our cleaning system. At the end of every 30-day period, we collected water sample from the output of the geyser. As phase 1 does not have any cleaning system, we could directly collect the water from the outlet of the geyser. However, in phase 2, the cleaning system is activated and only after that the water sample is collected from the geyser. The water samples are collected and submitted for testing at an external water testing laboratory in Chennai, India. The laboratory tests the water for total dissolved salts and total hardness, and we got the results directly from them. The results of each period are tabulated and plotted in the form of a graph.

Phase 1: without scale reduction system

Phase 2: with scale reduction system.

Table 1 Total dissolved solids in mg/l relative to the number of days

	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180	Day 210	Day 240
Phase 1	1132	1137	1140	1149	1158	1165	1174	1182
Phase 2	1129	1131	1133	1133	1135	1138	1139	1141

4.2 Total Dissolved Solids

The water sample is collected from the geyser at the end of every 30-day period to test for content of dissolved solids present in the water. Both the phases are started on the same day. At the end of the 30-day period, water sample is collected from the outlet of the geyser and sent for testing to an external water testing laboratory. It can be seen from the results table that the value of total dissolved solids increases rapidly in phase 1 geyser compared to phase 2 geyser. In phase 1, the scale development is more, and hence, there is a possibility of those salts on the walls of the geyser to be dissolved into the new water that has entered the geyser. In phase 2 geyser, the cleaning system removes the salt clearing the internal walls of the geyser of any salt. Thus, the rise in value is minimal for phase 2 (Table 1).

4.3 Total Hardness Content

The water sample is collected from the geyser at the end of every 30-day period to test for total hardness content present in the water. Both the phases are started on the same day. At the end of the 30-day period, water sample is collected from the outlet of the geyser and sent for testing to an external water testing laboratory. Hardness of water generally depends on the area of source of water and increases with frequency of usage of geyser since more salts get deposited over a period of time as evident in the results of phase 1. However, in phase 2, the geyser with the cleaning system is able to reduce the rate of increase of hardness content because the cleaning system removes the salts deposited from the internal wall of the geyser. Thus, we are able to control the rate of increase of hardness to a considerable extent (Table 2).

Table 2 Total hardness content in mg/l relative to the number of days

	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180	Day 210	Day 240
Phase 1	379	409	439	478	498	553	581	603
Phase 2	382	385	391	402	462	449	465	478

Table 3 Scale formation in mm relative to the number of days

	Day 30	Day 60	Day 90	Day 120	Day 150	Day 180	Day 210	Day 240
Phase 1	0	0.16	0.39	0.53	0.67	0.89	1.0	1.15
Phase 2	0	0	0.1	0.12	0.15	0.18	0.22	0.24

4.4 Scale Formation

Scale formation is the layer of salt deposited on the internal wall of the geyser due to the salts present in the water and frequent heating and cooling of the water present inside the geyser. This layer of scale's thickness varies at different points on the geyser. Thus, we take the average of five readings. The task of measuring the scale thickness is a tedious task as the thickness value is in millimeters. Thus, in order to obtain accurate result, we peeled a small layer of the scale from the geyser wall and measured using a digital gauge. A small layer of scale can be peeled or scraped off the wall. This layer is highly delicate and fragile, and so the utmost care was taken to take the reading as soon as it is peeled within the geyser. Initial readings were tough as the scale layer was of negligible thickness. However, with increase in time, it was possible to obtain the readings by repeated trial and errors (Table 3).

5 Conclusion

It is clear from Fig. 4 that the growth of scale inside the geyser has been brought down to a considerable extent in phase 2 compared to phase 1. The reduced scale film also helped with maintaining the hardness value of the water as shown in Fig. 3, since the

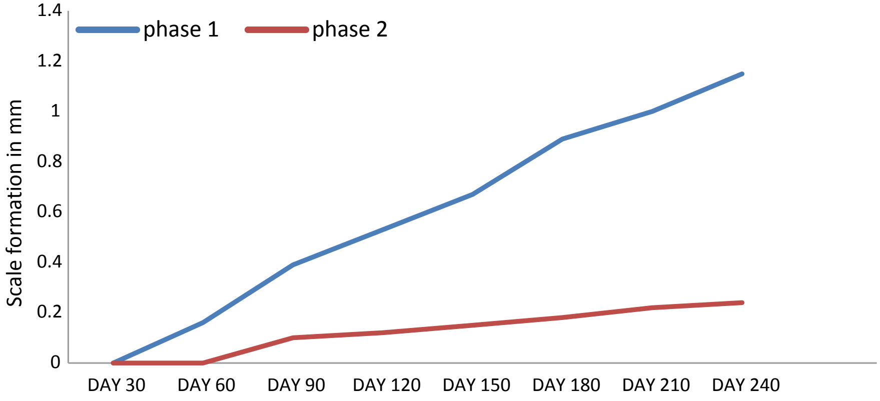

Fig. 4 Comparison of scale formation in mm

presence of salts is lesser inside the geyser. The total dissolved solids in the water are also maintained as shown in Fig. 2 as there is very limited amount of scale film for it to dissolve into. From the overall experiments and analysis performed, we can conclude that the cleaning system proved successful in its task by efficiently removing the scale deposition on geyser with minimal labor. This has had a significant effect on the life of the geyser and improves the durability as such. The installation of this setup is also simplified and easier, thus reducing the maintenance cost of the geyser. Servicing a geyser is a tedious task. It either requires an expert or had to be taken to a service center for servicing. The geyser has to be opened every time, and scales have to be scrapped using an abrasive sheet or any other scale removal method every time. The float system substitutes this process, making the task easier and reducing the scale formation to a considerable extent. Furthermore, the efficiency of the geyser is also increased by consuming less energy when compared to energy consumption during presence of scales in geyser. This can be justified the presence of less salts in the water. Overall, the experiment was successful, and the results are in favor.

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