

IMPACT OF INTERRUPTION OF ANTISCALANT DOSING OR CLEANING BALLS CIRCULATION DURING MSF PLANT OPERATION¹

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ABSTRACT

MSF desalination plants occasionally experience interruption of antiscalant dosing or circulation of cleaning balls. The interruption may be either due to sudden system failure or the system is to be isolated for maintenance works. In such situations, specific operational procedures are normally adopted to counter the consequences of mal-operation of antiscalant dosing or cleaning balls systems. The various corrective measures that are normally adopted by SWCC MSF plants to mitigate the consequences of malfunctions of the antiscalant dose or the on-line ball cleaning systems are reviewed. The aim of this study is to establish operating conditions and consequences when antiscalant dosing or ball circulation is interrupted. The established operating conditions are intended to be used as a guide to recommend appropriate lines of actions to be followed by SWCC MSF plants to counter the impact of interruption of antiscalant dosing or cleaning balls circulation.

Two series of evaluation tests were carried out. In the first series, extensive pilot plant tests were conducted to obtain preliminary assessment on the impact of sudden or gradual interruption of antiscalant dosing and the consequences when operating without cleaning balls circulation. In the second series, an evaluation test was conducted in one of the MSF distillers of Al-Khobar Phase-II plant to explore the consequences when antiscalant dosing was suddenly interrupted and stopped completely.

The pilot plant experimental results revealed that when antiscalant dosing was suddenly interrupted or stopped, the plant could safely operate without scale formation

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for a maximum period of 24 hours. When the MSF pilot plant was operated at TBT of 90°C and brine recycle concentration ratio of 1.4 without circulation of cleaning balls, the experimental results revealed that the effectiveness of a polycarboxylate based antiscalant in inhibiting scale formation was quite different compared to that of a phosphonate based antiscalant. Ball cleaning operation is highly influencing and effective when phosphonate based antiscalant is used. It has also been found that the threshold inhibition of the phosphonate based antiscalant with no ball cleaning at a dose rate of 1.0 ppm was more effective than that when using a relatively high dose rate of 3.0 ppm. Over-dosing of phosphonate based antiscalant with no ball cleaning was responsible for formation of excessive sludge. Based on the preliminary tests which were carried out in the MSF pilot plant, it is recommended that plants which are using phosphonate based antiscalant have to review the corrective actions which they normally follow in case of interruption of ball circulation

Al-Khobar Phase-II plant evaluation test revealed that it is quite safe to operate the MSF distiller without antiscalant dosing for a maximum period of three hours.

1. INTRODUCTION

1.1 Scale Control

Scale formation on heat transfer surfaces, which is one of the basic problems in the desalination of seawater, can be effectively controlled or minimized by the addition of chemical additives and use of on-line ball cleaning. A number of optimization tests have been carried out by SWCC thus leading to successful operation at low antiscalant dose rates [1-9]. Recommended dose rates to SWCC in 1981 were 12.5 and 4.5 for TBT of 110 and 90°C respectively [3] and are currently reduced to only 2.0 and 0.8 ppm for the respective temperatures. This significant reduction in dose rate is attributed to several factors such as improvement in chemical formulation, adoption of on-line sponge ball cleaning and plant operator awareness to reduce chemical dosing while maintaining effective plant performance.

Although the formation of scale is combated and controlled by threshold treatment with the use of antiscalant, its complete prevention is impracticable. Sludge or distorted scale is also formed because of threshold treatment, which is deposited on tube metallic

surfaces, and induces resistance to heat transfer. The combined use of chemical additives and on-line tube cleaning has been proved to be the most cost effective means to combat scale formation and to avoid frequent acid cleaning [10-12]. All SWCC MSF plants are using on-line sponge ball cleaning.

1.2 Interruption of Antiscalant Dosing or Circulation of Cleaning Balls

Commercial MSF desalination plants sometimes experience interruption of antiscalant dosing or circulation of cleaning balls. Either the interruption may be due to sudden system failure or the system is needed to be isolated for maintenance works. In such circumstances, commercial plants normally adopt certain operating procedures to counter the consequences of mal-operation of antiscalant dosing or cleaning balls systems.

The corrective measures that are normally adopted by SWCC MSF plants to mitigate the consequences of malfunctions of the antiscalant dose or the on-line ball cleaning systems are varying. Generally, there are three different approaches, which are normally followed by SWCC MSF plants to counter the interruption and failure of antiscalant dosing system. Al-Khafji, Shoaiba and Yanbu plants generally resort to shut down the distiller immediately or employ cold circulation mode. The second group of plants, which include Al-Jubail, Al-Khobar and Shuqaiq, utilize continuous circulation of cleaning balls and reduce the top brine temperature to less than 90°C. Jeddah plants, which represent the third approach, normally use the standby acid dosing system when the antiscalant dosing system is malfunctioned.

The remedial actions, which are normally followed by SWCC MSF plant when the ball cleaning system is inoperative, are also quite different. Al-Jubail plant prefers to solely increase the antiscalant dose rate by 50 per cent. Other plants favor the increase of antiscalant dose rate coupled either with the increase of the make-up flow such as Al-Khobar or Al-Khafji plants or with the reduction of the distiller production load as normally practiced in Yanbu plant. Jeddah plants can tolerate operation without ball cleaning for a maximum period of one month when using phosphonate based antiscalant and six months with the use of polycarboxylate based antiscalant.

Very little research work has been published to report the impact of the improper functioning of the antiscalant dosing or on-line ball cleaning systems on the thermal performance of the MSF distillers. Al-Sofi, et.al [13] reported the performance of MSF pilot plant when operated with extremely low dose rates with and without on-line sponge rubber ball cleaning. The impact of gradual dose rate reduction of phosphonate-base antiscalant on the thermal performance of the MSF pilot plant operating with a TBT of 90°C, was investigated. The antiscalant dose rate was reduced in a step-wise mode from 1.0 ppm to 0.0 ppm in five days time. The brine heater fouling factor increases, yet gradually, with the reduction in antiscalant dose rate. The pilot plant was also operated without ball cleaning at TBT of 90°C and with a 1 ppm dose rate of phosphonate base antiscalant. Very gradual increase in the fouling factor of the brine heater was observed.

Al-Fraj et al. [14] reported the trials carried out on two commercial MSF distillers that were operated at TBT of 103°C and 105°C without the circulation of cleaning balls using two different types of antiscalants. To alleviate the consequences of operating without ball circulation, the antiscalant dosing rates were increased by 50 to 100%.

The objectives of this paper are two folds:

- (1) To establish operating conditions and consequences when antiscalant dosing or ball circulation are interrupted.
- (2) To recommend appropriate lines of actions that is to be followed by commercial MSF plants to counter the impact of interruption of antiscalant dosing or cleaning balls circulation.

2. EXPERIMENTAL METHODOLOGY

Two series of evaluation tests were carried out. In the first series, extensive pilot plant tests were conducted to obtain preliminary assessment on the impact of sudden or gradual interruption of antiscalant dosing and the consequences when operating without cleaning balls circulation. In the second series, an evaluation test was conducted in one of the MSF distillers of Al-Khobar Phase-II plant to explore the consequences when antiscalant dosing was suddenly interrupted and stopped completely.

2.1 Pilot Plant Test

2.1.1 Test Location

For preliminary evaluation tests the MSF pilot plant of RDC was selected. This pilot unit consists of 4 stages in the heat recovery section and 2 stages in the heat rejection section. Its design capacity is 20 ton/day and it has all the important features of an MSF commercial plant. Make-up seawater can be given additive and/or acid treatment inclusive of external deaeration and decarbonation. Scale control by antiscalant chemical is complemented by two separate rubber ball cleaning loops. There is also a provision of acid cleaning of heat transfer tubes (brine heater) with and without recovery section tubes.

It can provide sufficiently good initial indication for the purpose of the study. Heat transfer coefficients and fouling factors were monitored during the tests.

2.1.2 Test Plan and Conditions

Two successive groups of tests were carried out. In the first group, the impact of interruption of antiscalant dosing on the thermal performance of the MSF pilot plant was thoroughly investigated. In the second subsequent group, the consequences of operating the pilot plant without ball cycling in the brine heater and heat recovery section were explored. The evaluation tests of the two groups are detailed as follows:

Group -I

In the first group, two evaluation tests were carried out to examine the consequences of interruption of antiscalant dosing which are :

1. Stepwise reduction of dose rate of phosphonate or polycarboxylate based antiscalants from 1.0 ppm down to 0.0 ppm at TBT of 90°C.
2. Abrupt dose rate reduction from 1.0 ppm to 0.0 of phosphonate and polycarboxylate based antiscalants at TBT of 100 °C.

Group-II

In the second group, two evaluation tests were carried out to study the impact of cleaning balls interruption on the unit performance.

1. The pilot plant was operated without ball cycling at TBT of 90°C using either phosphonate or polycarboxylate based antiscalants at TBT of 90°C with a dose rate of 1.0 ppm.
2. To investigate the impact of antiscalant overdosing, the pilot plant was operated with no ball circulation at TBT of 100°C and with a relatively high dose rate of 3.0 ppm of the sludge forming phosphonate based antiscalant.

2.2 Commercial Plant Test

Unit # 8 of Al-Khobar Phase-II MSF plant was selected to explore the consequence when antiscalant dosing was suddenly interrupted and stopped completely. The evaporator is designed as additive control process with recirculating brine flow regime through the cross tube configuration. The distiller is designed to produce 5 MIGD at TBT of 90 °C with provision to go up in production to 6.7 MIGD at TBT of 115 °C. The distiller is currently operating at TBT of around 90°C. Scale control is attained through the combined continuous injection of polycarboxylate based antiscalant with a dose rate of 1 ppm and circulation of cleaning balls. On-line ball cleaning operation is normally carried out once every shift and with 9 cycles per shift.

3. RESULTS AND DISCUSSION

3.1 Pilot Plant Tests

3.1.1 Antiscalant Interruption

3.1.1.1 Stepwise Reduction of Antiscalant Dose Rate

Before assessing the impact of sudden interruption of antiscalant dosing and as a precautionary step and in order to make a direct comparison between the performances of two antiscalants of different chemical structures which are polycarboxylate and phosphonate based antiscalants, two preliminary evaluation tests were first carried out. The primary objective of these two tests was to determine the impact of gradual reduction of antiscalant dose rate when the MSF pilot plant was operating at 90°C, brine concentration ratio of 1.4 and the ball cleaning circulation was in normal operation. Figures 1 and 2 show the variation of the overall heat transfer coefficient (OHTC) and the fouling factor (FF) of the brine heater for phosphonate and polycarboxylate based antiscalants, respectively.

Figure 1 reveals that the OHTC and the FF remained virtually constant when the dose rate of the phosphonate based antiscalant was reduced in a stepwise mode from 1.0 ppm to 0.4 ppm. Conversely, when the dose rate was reduced further to 0.2 ppm, the unit started to be fouled and the FF increased from 0.05 to 0.1 m²K/kW. When the antiscalant dosing was completely stopped, the FF increased significantly from 0.1 to 0.17 m²K/kW.

Figure 2 demonstrates that for polycarboxylate based antiscalant, the OHTC and FF during the dose rate range of 0.8 ppm down to 0.2 ppm were almost maintained constant and there was no indication of scale formation. However, when the antiscalant dosing was completely discontinued, the FF increased significantly from 0.05 to 0.23 m²K/kW within three days time.

Comparison of the test results depicted in Figures 1 and 2 disclose that phosphonate and Polycarboxylate based antiscalants will allow pilot plant operation safely down to a dose rate of 0.4 at TBT of 90 °C with continuous circulation of cleaning balls.

3.1.1.2 Abrupt Reduction of Antiscalant Dose Rate

Two evaluation tests were carried out to determine the impact of sudden interruption of antiscalant dosing on the performance of the MSF pilot plant. The unit was operated at a TBT of 100°C, brine concentration ratio of 1.4 and with continuous cleaning ball circulation using two different antiscalants. The test results of the two examined antiscalants, which are shown in Figures 3 and 4 disclose that the two antiscalants are more or less exhibiting the same behavior. The OHTC and the FF of the brine heater were virtually remained constant for a period of about 24 hours. Although the antiscalant dosing was completely discontinued during this 24 hour period, the residual quantity of antiscalant succeeded in suppressing scale formation. It has been concluded that if antiscalant dosing is suddenly interrupted or stopped, the pilot plant can safely operate for a maximum period of 24 hours.

In spite that the MSF pilot plant is simulating the operational performance of a commercial MSF distiller to a large extent, there are still some operational disparities between the two units. Particularly the residence time of the brine recycle during its

passing through the tubes of the brine heater and heat recovery section of the pilot plant, is much lower than that experienced in the commercial unit. It is thus expected that when the antiscalant dosing is suddenly stopped in a commercial plant, the safe period that would not seriously affect the plant thermal performance shall be much less than 24 hours. It is recommended that an actual test is to be conducted in a selected commercial distiller to identify the consequences of completely stopping the antiscalant dosing for a prescribed period of time (e.g. 8 hours).

3.1.2 Interruption or Failure of On-line Ball Cleaning System

The MSF pilot plant was first operated at TBT 90°C and brine recycle concentration ratio of 1.4 without circulation of cleaning balls using successively two different antiscalants (phosphonate and polycarboxylate based antiscalants). The results of the two evaluation tests are shown in Figures 5 and 6. Figure 5 shows the impact of no-cleaning ball circulation on the performance of the MSF pilot plant using phosphonate based antiscalant. For the first 80 hours of operation, suspension of cleaning ball circulation did not result in deterioration of the unit thermal performance and it can thus be considered as a tolerable time margin. Afterwards, the FF of the brine heater started to rise sharply reaching the unit design fouling factor in a period of almost 320 hours. When the ball cleaning circulation was resumed the FF dropped significantly to a value which was comparable to the FF value at the test onset. This behavior indicates that the scale formed was in sludge form and which can easily be removed by ball circulation.

Figure 6 reveals that the effectiveness of polycarboxylate based antiscalant in inhibiting scale formation when the ball cleaning system was inoperative, was quite different compared to that of phosphonate based antiscalant. In spite of the fact that the pilot plant was operated for a period of more than 350 hours without ball cleaning, the unit thermal performance was very slightly influenced which was reflected in the very low rise of the brine heater fouling factor. When ball cleaning was resumed after the elapse of 370 hours of operation without ball cleaning, the FF was slightly reduced. It can thus be derived that the influence of operation without ball cleaning (for a period of 370 hours) when polycarboxylate based antiscalant is insignificant.

Direct comparison of Figures 5 and 6 show that the ball cleaning operation is highly needed and it is effective when phosphonate based antiscalant is used. This deduction is consistent with the findings reported earlier by Al-Zahrani, et.al [6].

To investigate further the impact of no-ball cleaning operation on the effectiveness of phosphonate based antiscalant, two consecutive tests were carried out. The results are shown in Figure 7. In the first test, the pilot plant was operated at TBT of 100°C without ball cycling and with a relatively high dose rate of phosphonate based antiscalant, that was 3 ppm. In a period of 130 hours the brine heater FF almost approached the design value. Ball cleaning cycling was resumed and the original FF of the unit was restored. The test was then carried out with a lower dose rate of 1.0 ppm. It took around 200 hours – a period which was longer than that obtained with a dose rate of 3 ppm - to reach the targeted FF. The threshold inhibition of the phosphonate based antiscalant with no ball cleaning at a dose rate of 1.0 ppm was thus more effective than that when using a relatively high dose rate of 3.0 ppm. Over-dosing of the phosphonate based antiscalant with no ball cleaning was responsible for formation of excessive sludge. The majority of SWCC's MSF plants as described in Section 1.2 prefer to increase antiscalant dose to counter the negative impact of interruption of cleaning balls circulation.

Based on the preliminary tests, which were carried out in the MSF pilot plant, it is recommended that plants which are using phosphonate based antiscalant have to review the remedial actions, which they follow in case of interruption of ball circulation.

3.2 Commercial Plant Test

An evaluation test was conducted in unit # 8 of Al-Khobar Phase-II MSF plant to explore the consequences when antiscalant dosing was suddenly interrupted and stopped completely. The evaluation test was carried out on Monday 28th July, 2004. At 7.10 a.m. the antiscalant dosing was completely stopped and normal ball cleaning operation was maintained throughout the whole test period. Comprehensive chemical analyses were carried out of the most important liquid streams which included:

- Seawater make-up

- Brine recycle entering and leaving the heat recovery section
- Brine recycle leaving the brine heater
- Brine blow down
- Product water

The most important parameters which were monitored during the test were pH, conductivity, TDS, chlorides, M-Alkalinity, loss of total alkalinity, calcium, magnesium and total hardness.

Figure 8 shows the variation of loss of total alkalinity (LTA) of the brine recycle leaving the brine heater with time. The LTA shall give an estimate of the quantity scale deposited in the heat recycle and brine heater. Point A in Fig. 8 represents the condition at the onset of the test and when the antiscalant dosing was completed stopped. During the period of antiscalant interruption, the LTA started to increase. During the first three hours the LTA increased gradually from 1.0 ppm to 5.5 ppm as indicated by line AB. Afterwards LTA increased exponentially with time and at point C it reached a value of around 20 ppm after five hours. Antiscalant injection was then resumed with a relatively high dose rate of 2 ppm for a 30 minutes period and then reduced to normal dose rate of 1 ppm. In the mean time, the ball cleaning system was started and kept in operation continuously for four hours.

The LTA dropped significantly and was maintained consistently below 5 ppm. It is concluded a period of three hours can be considered as a quite safe period to operate the MSF distiller without antiscalant dosing. During this three hours period the residual antiscalant in the brine recycle was effective in the control of scale formation and maintain the LTA within a safe limit.

4. CONCLUSIONS

1. The various corrective measures that are normally adopted by SWCC MSF plants to mitigate the consequences of malfunctions of the antiscalant dose or the on-line ball cleaning systems are reviewed.
2. The operating conditions and consequences when antiscalant dosing or ball circulation was interrupted using two different antiscalants were established.

3. The phosphonate and polycarboxylate based antiscalants will allow pilot plant operation safely down to a dose rate of 0.4 at TBT of 90 °C with continuous circulation of cleaning balls.
4. The extensive pilot plant experimental results revealed that when antiscalant dosing was suddenly interrupted or stopped, the plant could safely operate without scale formation for a maximum period of 24 hours.
5. When the MSF pilot plant was operated without circulation of cleaning balls, the effectiveness of polycarboxylate based antiscalant in inhibiting scale formation was quite different compared to that of phosphonate based antiscalant. Ball cleaning operation is highly effective when phosphonate based antiscalant was used. Conversely, the influence of operation without ball cleaning on the performance of the pilot plant using polycarboxylate based antiscalant is insignificant.
6. It has also been found that the threshold inhibition of phosphonate based antiscalant with no ball cleaning at a dose rate of 1.0 ppm was more effective than that when using a relatively high dose rate of 3.0 ppm. Over-dosing of phosphonate based antiscalant with no ball cleaning was responsible for formation of excessive sludge.
7. Al-Khobar Phase-II plant evaluation test revealed it is quite safe to operate the MSF distiller without antiscalant dosing for a maximum period of 3 hours.

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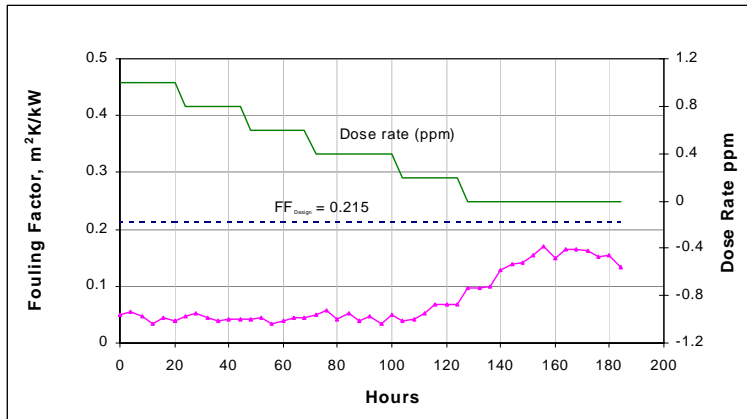
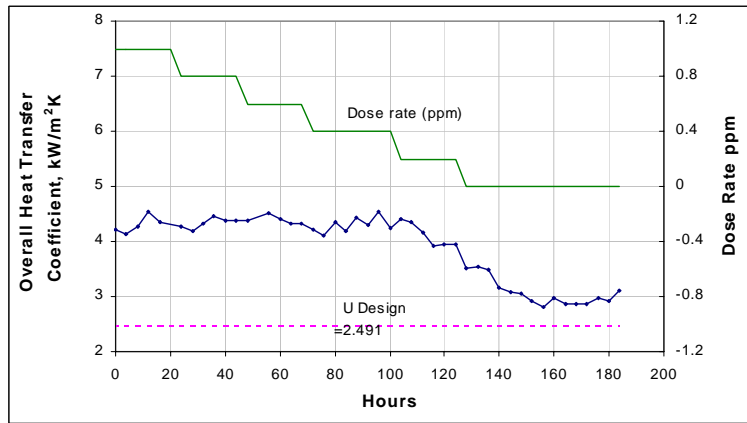


Figure 1. Impact of gradual dose rate reduction of phosphonate based antiscalant on brine heater Performance at TBT of 90 °C

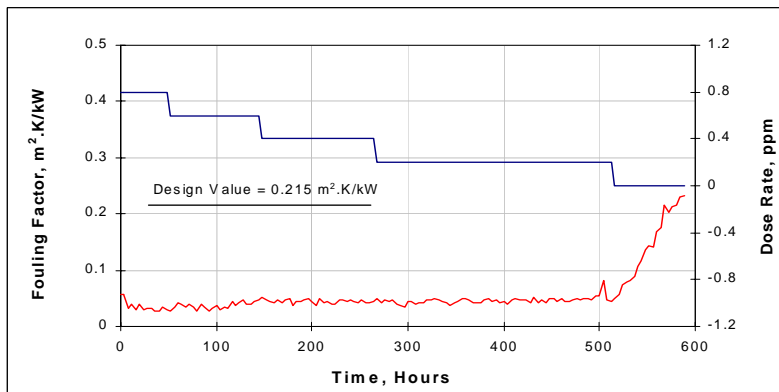
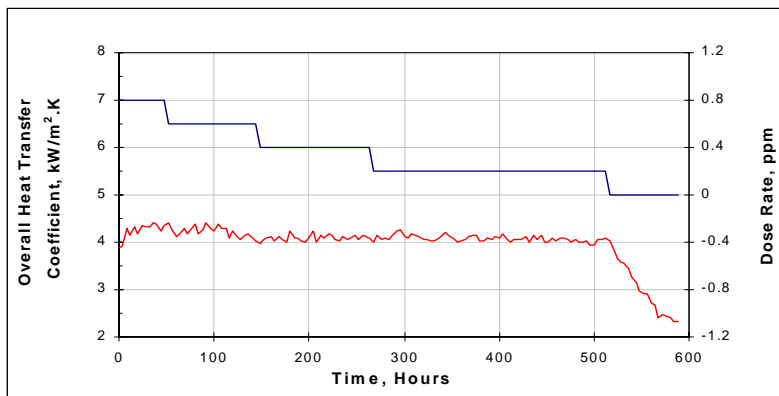


Figure 2. Impact of gradual dose rate reduction of polycarboxylate based antiscalant on brine heater performance at TBT of 90°C

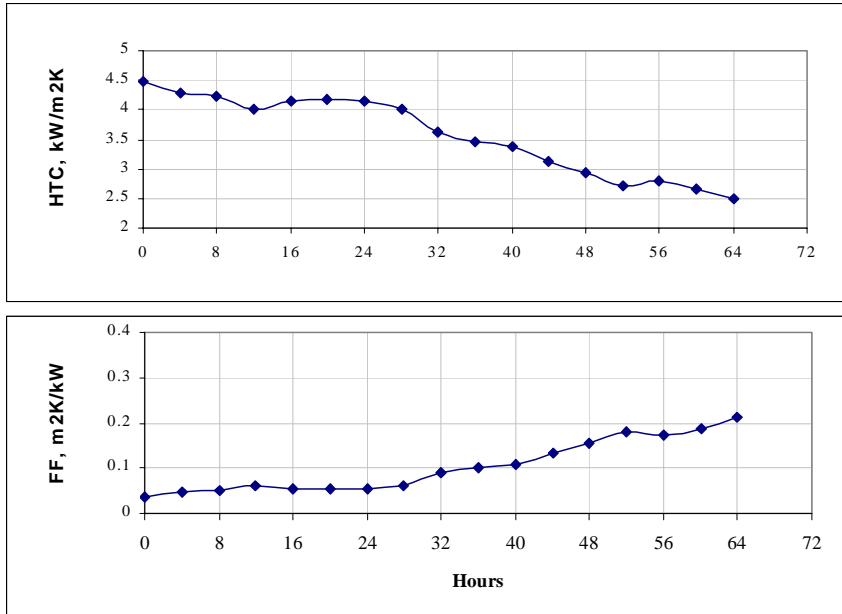


Figure 3. The impact of sudden cutting of phosphonate based antiscalant dosing at TBT 100 °C and 1.0 ppm with continuous cycling of cleaning balls on the performance of MSF pilot plant

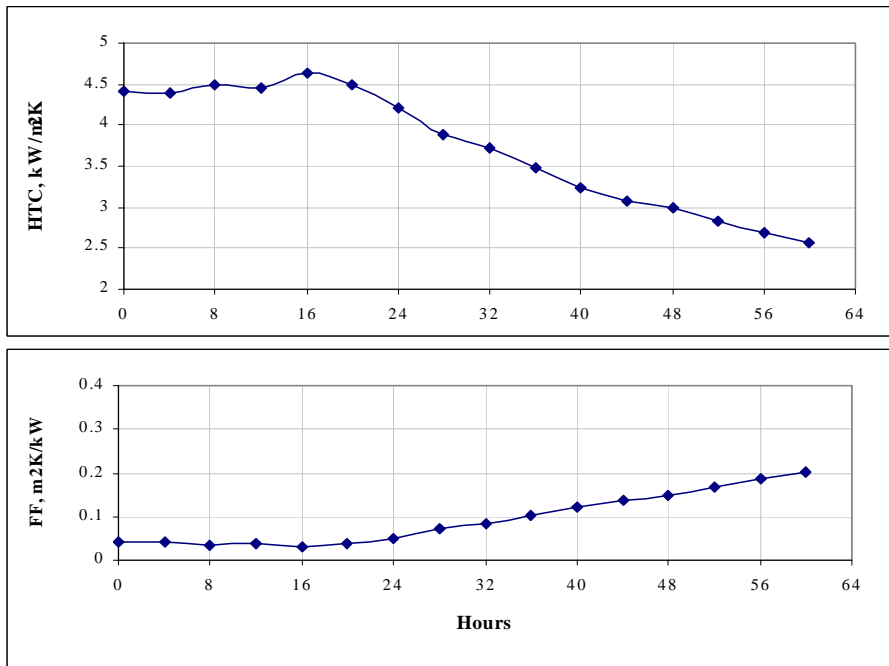


Figure 4. The impact of sudden cutting of polycarboxylate based antiscalant dosing at TBT 100°C and 1.0 ppm with continuous cycling of cleaning balls on the performance of MSF pilot plant

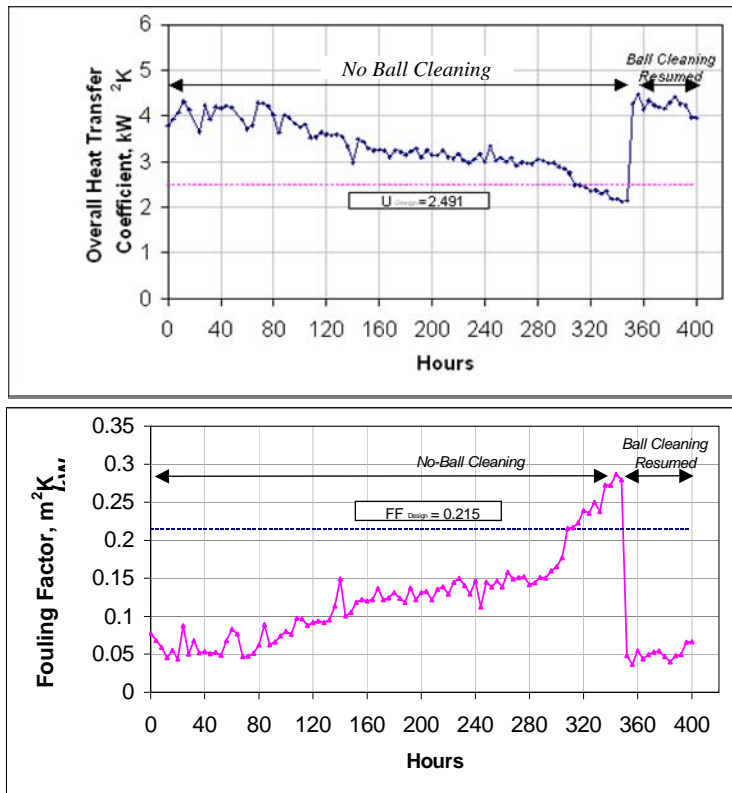


Figure 5. Balls cleaning interruption with dose rate of 1.0 ppm of phosphonate based antiscalant at TBT of 90°C

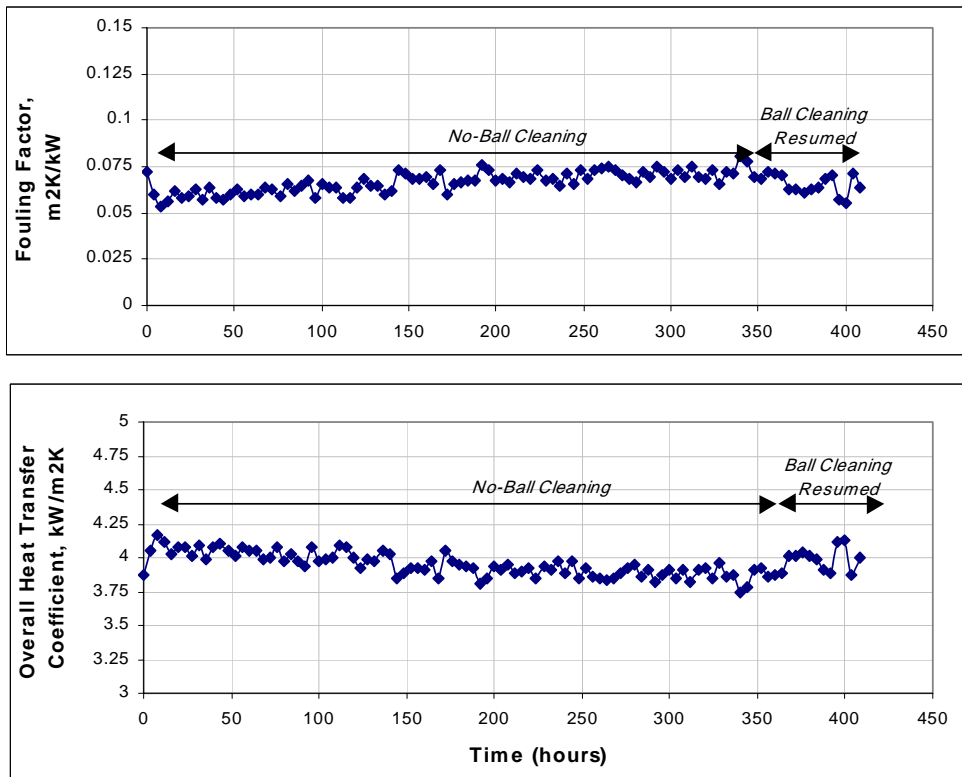


Figure 6. Balls cleaning interruption with dose rate of 1.0 ppm of polycarboxylate based antiscalant at TBT of 90 °C

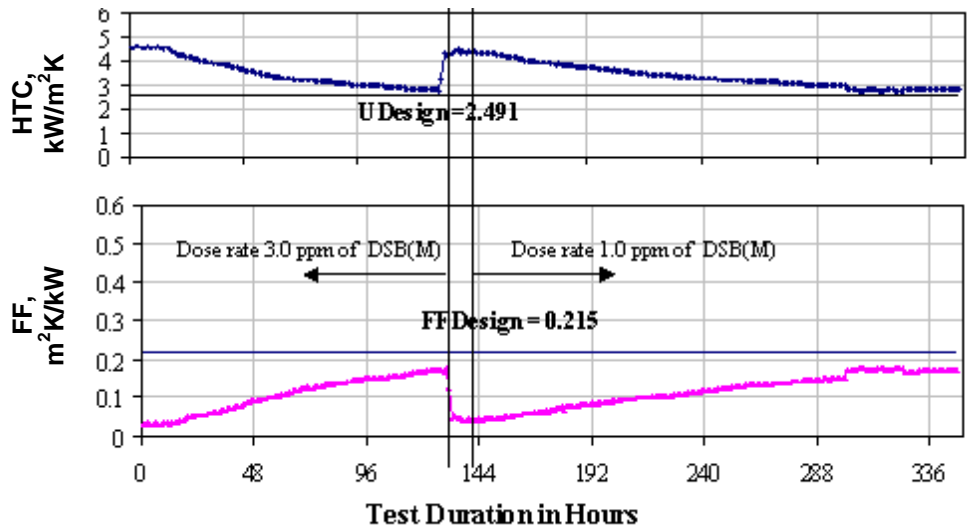


Figure 7. Balls cleaning Interruption with dose rate of 1.0 and 3.0 ppm of DSB(M) at TBT of 100 °C

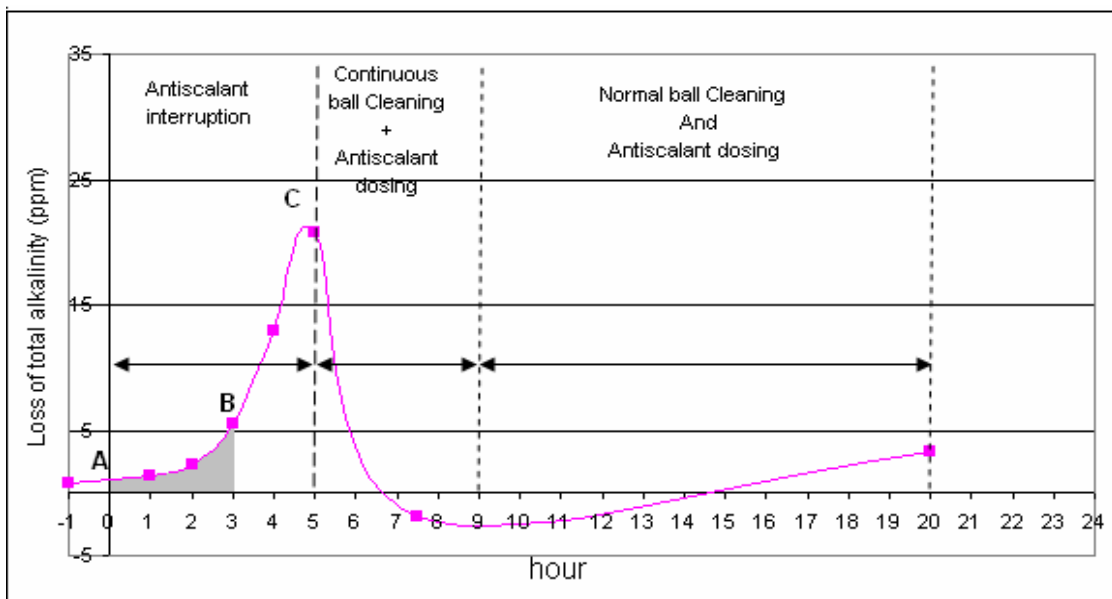


Figure 8. Variation of loss of total alkalinity with time during antiscalant interruption test in Al-Khobar Phase-II Plant