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Heat transfer measurement as a criterion for performance evaluation of scale inhibition in MSF plants in Kuwait

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Abstract

All Arab Gulf states experience a shortage of fresh water resources. The deficiency is made up for by desalinating seawater, mainly by the multi-stage flash (MSF) evaporation technique. Fouling in MSF distillers has been occupying researchers for many years. Much work has been done and more is yet to come in order fully to understand the role of various components and their interaction including the effectiveness of scale control techniques. Tis work is based primarily upon visual and reported observations of fouling in various parts along the flow path of brine solutions in MSF distillers. The analysis aimed at proposing certain sequences of scale forming reaction steps and to suggest certain experiments that will verify the validity of the proposed reaction mechanism. Scale precipitation inside tubes is not only from initial scale formation under pressure but also due to nucleates recirculating from flash chambers back into the heat gain exchanger tubes because of brine recycling. This work introduces an experimental technique that appears to be reliable and economical for evaluating the performance and identifying limitations of scale inhibition in MSF plants. Data and analysis of results obtained during the series of experiments are presented.

Keywords: Multi-stage flash (MSF); Fouling; Scale inhibition; Heat transfer measurement

1. Introduction

Combating the formation and deposition of scale and sludge on internal surfaces of heat transfer tubes of brine heaters and heat recovery sections of multi-stage flash MSF seawater desalination plants has been and continues to be at the center of attention of researchers and developers working in this field as well as the owners of these plants. The last couple of decades have

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witnessed serious efforts by chemical developers who are attempting to extend the top range of temperatures where effectiveness of chemicals used in suppressing formation and deposition can be prolonged [1–4]. Furthermore, certain advances have been attained, particularly by owners of MSF plants, in opti-mizing the use of available chemical additives [5–8].

Inhibition of scale in MSF plants is achieved by one of the following treatment methods:

- Use of acid to cause depletion of carbonate present in seawater. This is known as the acid treatment method.
- Use of commercially available scale inhibitors, known as the chemical additive treatment method.
- Combined use of the above two, i.e., use of scale inhibitors at a reduced dosing rate with partial depletion of carbonate by acid. This is known as the hybrid treatment method.

Acid treatment is an old method that has been used in the early MSF desalination plants. In this method acid, mostly H_2SO_4, reacts with the carbonate present in seawater. This reaction yields H_2O and CO_2, hence preventing formation of $CaCO_3$. Precise control of pH is very crucial for both the inhibition of scale and prevention of corrosion.

In the second and third methods certain chemical additives, when dosed at the rate of few mg/L into seawater, are capable of suppressing or delaying the initiation of scale formation. In addition to this, such chemical additives have another effect which causes precipitated particles to remain dispersed and suspended in the flowing water by preventing adhesion between individual particles and between particles and internal tube surfaces. However, treatment with chemical additives must also be supported by mechanical cleaning using sponge balls which help to maintain the internal tube surfaces clean and free of deposits.

The overall effectiveness of any of the above scale-inhibition mechanisms can, therefore, be determined and evaluated by measuring the decrease in heat transfer coefficients or the increase in fouling factors in the brine heater and heat recovery tubes of MSF plants. In view of the above, this paper presents the effects of scale-inhibition mechanisms such as the dosing of chemical additives on the rates of heat transfer at varying concentration of seawater.

Evaluation of scale control methodology and optimization thereof plus the review of plant and heat exchanger tube inspection reports [9,10] have led to comprehension of the proposed mechanism. Some recent analysis and review of published works, particularly those of Shams El-Din and his coworker Rizk [11,12] have had stimulating effects to look into the commonly and currently stipulated reaction mechanisms, more specifically the sequence events, i.e., reaction hierarchy or steps. Over the years there were instances when scale was predominantly reported in certain sections of MSF distillers where no one would expect any scale. There were also cases, yet seldom, that such predominance was of an overriding nature in those sections where no heavy scaling could be expected; further, it was absent from places where scale is believed and typically observed to be the heaviest [10].

It is worth noting that there is a wealth of experience on MSF distillation in general and scale control in particular in the Gulf Cooperation Council (GCC) states [2,9–13,15–19] and the world at large [2,20,21]. This paper is primarily based on local knowledge and experience.

2. Literature review

Alkaline scale formation in seawater distillation begets from the decomposition hydrolysis of seawater bicarbonate ions as process temperature is increased. The scales most observed that occurs in MSF distillers are found to be either $CaCO_3$ or