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Web-based monitoring and control to improve RO performance and reliability

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ABSTRACT

Application of RO membranes for water reclamation and desalination is growing significantly in recent years due to scarcity of water resource. In order to achieve stable operation and good performance, membrane system requires reliable monitoring and control in addition to skilled operating personnel. For industrial users of small to medium RO systems, operation failure and membrane damage are frequently observed due to inadequate technical knowledge of operating staff. With this in mind, Nalco has developed a web-based monitoring and control system, 3DT for Membrane (3DTfM), to assist small and medium scale users to achieve optimized system performance. In order to demonstrate its value, 3DTfM has been installed at a RO system treating boiler feed water at a power plant. This study is to illustrate the benefits of utilizing 3DTfM; namely stable antiscalant dosage, better ORP control, improved alarm management, and periodical service report of the system. After implementing 3DTfM, fluctuation of antiscalant dosage has been reduced from wider range of 0.5–10 ppm to narrower range of 1.8–2.2 ppm. In addition, exposure duration of ORP > 650 mV has also been reduced by 83%. It has also been noted that operation staff was able to perform timely Clean-In-Place (CIP) and necessary adjustment of RO system. Owing to stable control, CIP frequency was reduced for about 50%. In terms of tangible saving delivered by 3DTfM, it is estimated to be $10,000 and 18,000 for asset and chemicals, respectively.

Keywords: Cleaning; Control; Dosage; Monitoring; RO system

1. Introduction

Although RO membranes have gained increasing popularity for industrial water treatment, water reclamation, and seawater desalination in past decades, fouling remains a key challenge for most RO systems [1]. Different types of fouling could practically be minimized by mechanical, chemical or instrumentation means. In general, colloidal fouling is minimized by effective mechanical filtration with occasional use of filter aid. Biofouling is handled by oxidizing or non-oxidizing biocides or UV disinfection. Scaling is controlled by adding antiscalant or pH adjustment at the inlet of RO vessels. For most of the RO systems, antiscalant dosage has been adjusted manually or

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linked proportionally to flow meters. Today, data transmission devices are available to float the operating information onto the virtual internet world for remote monitoring of system performance [2–7]. While instrumentation and control are critical for stable operation of RO system, web-based monitoring facility is equally important to ensure that preventive maintenance works are carried out in a timely manner. However, there is still a gap to provide valuable integrated solution for accurate chemical dosage and real time monitoring, especially for small to medium scale RO systems. In view of this, Nalco has been refining its patented 3D TRASAR technology during the past decade and the enhanced version, 3DT for Membrane (3DTfM), was successfully applied for membrane systems management since 2010 [8].

3DTfM not only improves the dosage control capability for antiscalant, especially for fluctuated operating condition and feed quality of multi-train RO system, but also integrates Nalco 360 service to provide the real-time operation data monitoring and normalization functions. Customers can receive the normalized RO performance, system analysis, and alarms of any urgent system issues or Clean-In-Place (CIP) recommendations combined with the professional operation advice from Nalco 360 center. Key benefits of 3DTfM are: (1) stable antiscalant dosage which can cause fouling at excessive dosage and scaling at lower dosage; (2) floating the operating data on the web and sending the real-time warning of critical alarms which can prevent irreversible fouling or oxidative damage; and (3) sending periodical service report which provides better understanding of the status and planning for preventative maintenance. 3DTfM could also provide the ORP surge protection facility and changing the operating set points remotely.

Fig. 1 shows the installation of a 3DTfM skid at the site. The operating information (flow and pressure) was captured from RO system, and transmitted via analog input module to the controller before being sent to the Nalco server together with the ORP, pH, conductivity, and antiscalant dosage data directly obtained via the controller.

Objective of this study is to evaluate the performance characteristics of 3DTfM for the managing of RO system located at a power plant.

2. System information and condition

RO feed water is clarified surface water and passing through multimedia filter and cartridge filter before reaching RO system. In addition to colloidal fouling, biofouling was reported to be the other reason of frequent chemical cleaning. Owing to oxidative damage experienced in the past, free residual chlorine (FRC) was strictly controlled at <0.1 ppm at the outlet of MMF before the installation of 3DTfM. Membrane replacement frequencies for stage-1 and stage-2 were reported to be approximately 1 and 2 years, respectively, either by irreversible fouling or membrane degradation. Thus, installation of 3DTfM was recommended to improve the situation.

Fig. 1. 3DT for membrane skid installed at site.

This is the first 3DTfM unit, installed at a power plant in Asia Pacific region to demonstrate added values to RO system. RO system information and configuration are as follow:

- Production: 105 m^3/h at 78% recovery.
- Configuration: Two stages (19:9 with six elements per vessel).
- Chemicals used: NaOCl, filter aid, sodium bisulfite (SBS), antiscalant, and non-oxidizing biocide.

3. Results and discussion

Results were collected from the first installation of 3DTfM in Asia Pacific region to demonstrate its values for managing the RO system treating boiler feed water at a power plant.

3.1. Stable dosage of antiscalant

For the first two weeks, after 3DTfM has been commissioned and operated continuously, baseline antiscalant dosage was found to be fluctuated between 1.5 and 4.5 ppm with the spike of >5 ppm due to frequent system shutdown and contamination of feed water. Thus, monitoring period was prolonged for few more months. Exposure period beyond the design dosage of 2 ppm was analyzed for baseline and control. Table 1 shows, the comparison of exposure period for three different conditions. Without 3DTfM control (baseline), membranes were exposed to >2.2 ppm of antiscalant for 50% of period. Overdose of antiscalant could potentially cause organic fouling. In addition to overdose condition, membranes encountered <1.8 ppm for 44% of period which could lead to potential scaling due to insufficient antiscalant dosage. Target dose of 1.8–2.2 ppm was observed only for about 6% of period without 3DTfM control. On the other hand, antiscalant dosage remained stable at 1.8–2.2 ppm for 80% of period under 3DTfM control. Scaling should be at minimal when antiscalant dosage is stable. It should also be noted that there was <1% exposure period at extreme condition of >3 ppm or <0.5 ppm throughout the period of 3DTfM control.

As shown in Fig. 2(a), fluctuation remained wide between 0.5 and 10 ppm with an average value of 3.2 ppm during the first 50 days without 3DTfM control. When the chemical dosing was put under control of 3DTfM, dosage of antiscalant has been averaged at 2.0 ppm. Longer period of stable dosage was also recorded during day 129–149 as illustrated in Fig. 2(b).

In terms of saving on antiscalant, average dosage during monitoring period was recorded at 3.2 ppm. Respective 90 percentile dosage was found to be much higher at 7.3 ppm. In other word, there have been many occasions of over-dose condition, causing potential organic fouling, and significant duration with under-dose condition which could lead to inorganic scaling. On the other hand, average dosage during control mode was calculated to be 2.0 ppm with fluctuation less than 0.2 ppm for 80% of the time. Respective 90 percentile dosage was estimated to be 2.2 ppm. When dosage of overall average was compared, saving of antiscalant was estimated to be approximately $11,500 per year at the antiscalant cost of $8.00 per kg.

In order to achieve accurate chemical dosage, experts from Nalco 360 team remotely provided service on PID tuning which requires experience and time. Operating staff at site normally lacks those skills and patience to complete the tuning which is critical to achieve stable dosage control of antiscalant by 3DTfM. When the operating staff at site is busy to change the set point to accommodate the changing feed water quality, experts from Nalco 360 team could also manage alarm and dosage set points on 3DTfM via internet access.

3.2. Surge protection of FRC

Although FRC has been regularly checked to maintain a concentration of <0.1 ppm at the outlet of MMF, there were frequent spikes of ORP which should be maintained at <250 mV according to membrane manufacturers. Otherwise, there is a risk of membrane being damaged by oxidative chemicals. Normally, residual FRC is scavenged or neutralized by the reducing agent such as SBS. Since, 3DTfM could provide 4–20 mA output signal, customer has decided to utilize the surge protection feature of 3DTfM by linking the analog output signal from 3DTfM to SBS dosing pump. It should be noted that there was more data points with >250 mV before SBS dosage was optimized than those after SBS dosage was optimized. Statistical analysis from the operating record of total period for 30-day cycle each indicated that there have been 24 and 4 h exposure at ORP > 650 mV before and after SBS dosage was controlled under surge protection mode. Comparison of exposure period at different ORP level is shown in Table 2.

Since, the operation of SBS dosing pump was put under control of surge protection mode from December 2012, ORP level has been tracked continuously and shown in Fig. 3(a) and (b). Average percentage of SBS dosing pump operation is recorded to be approximately 30% during that period depending on the ORP

Table 1
Comparison of exposure period at different antiscalant dosages

No.	Dosage range (ppm)	Exposure period		Impact
		Baseline (%)	Control (%)	
1	>2.2	50	13	Potential fouling
2	<1.8	44	7	Potential scaling
3	1.8–2.2	6	80	Good control

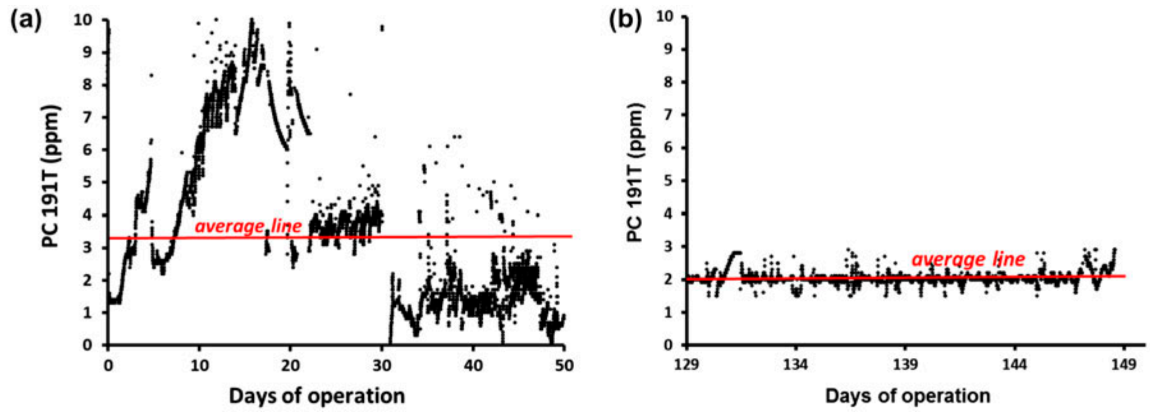

Fig. 2. Trend of antiscalant dosage during the monitoring period. (a) baseline consumption; (b) consumption under the control of 3DTfM.

Table 2
Comparison of exposure at different ORP levels

Exposure (hour)			
Before SBS optimized	After SBS optimized	Reduction of exposure (%)	ORP (mV)
231	131	43	>250
155	37	76	>280
131	31	76	>300
24	*4*	*83*	*>650*
11	0	100	>700
1	0	100	>750

level of the feed water. With the operation of SBS pump being operated continuously before using the surge protection facility of 3DTfM, SBS dosing was put at standby mode for about 70% of operating period under surge protection mode, leading to saving of about 70% SBS consumption which is estimated to be approximately $5,000 per year.

3.3. Early warning through key critical alarms

Since, 3DTfM has been commissioned and linked through internet, experts from Nalco 360 was able to send useful alarms to the concerned personnel to take necessary preventive actions such as dosing adjustment, filling chemical, product diversion, CIP, etc. In addition, customer was able to conduct necessary trouble shooting activities at earliest possible time. In general, triggered alarms and relevant impacts can be summarized as: (a) Feed Press High Alert ON: to trigger timely CIP; (b) Feed TRASAR Low Alert ON: to highlight potential scaling; (c) Feed ORP High Alert ON: to highlight potential oxidative damage.

When the feed pressure is high within a short interval, operating staff could check the SDI and quickly make necessary adjustment of pretreatment. When there is low TRASAR alarm, it is necessary to check and adjust the antiscalant dosing system to avoid potential scaling. If ORP is high, chlorine dosage of pretreatment and SBS dosage before RO membranes need to be checked and adjusted to avoid biofouling and membrane damage. Experts from Nalco 360 and site staff have also been working together to remove irrelevant alarms triggered during system shut down and to delay some of the alarms to avoid stray or faulty signals.

3.4. Weekly normalized report with analysis and recommendation

Weekly report with normalized trends (permeate flow, differential pressure, and salt passage) has been regularly sent out by experts from Nalco 360 service center to customer for review, planning, and execution of preventative maintenance. These reports include

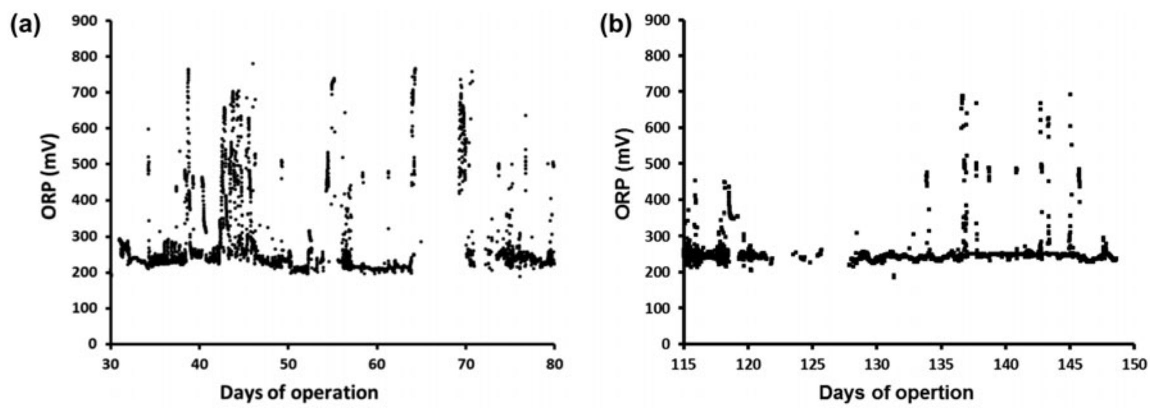

Fig. 3. Trend of ORP before and after surge protection mode.

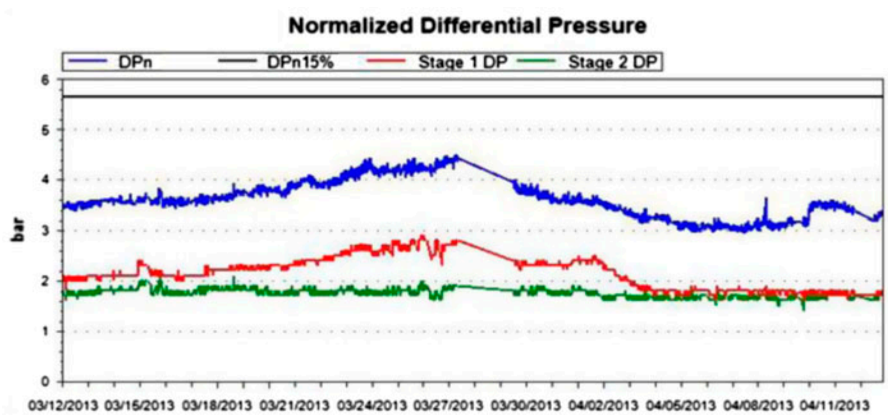

Fig. 4. Trend of normalized differential pressure.

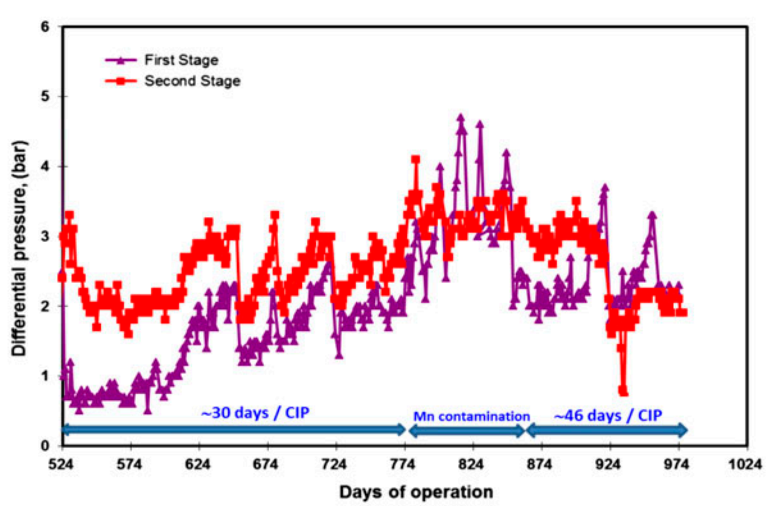

Fig. 5. Duration between each CIP before and after 3DTfM is put in control mode.

"corrective action analysis" which highlight the critical condition, possible cause, and recommended actions to be taken. Example of normalized differential pressure trend is illustrated in Fig. 4. Straight line in the figure appears when there is a system shut down. The figure also highlights the reference line of 15% change from baseline so that CIP could be triggered when differential pressure reaches the reference line.

3.5. Reduction of CIP frequency

During the initial period of 3DTfM trial, CIP frequency remained higher because of unexpected fouling by Manganese and biological contamination at the first stage of RO system. When those issues were resolved, CIP frequency was prolonged from 30 days in average to 46 days in average as shown in Fig. 5. It is an extension of CIP period for approximately 50%. Accordingly, there was a reduction of cleaning chemicals for about 50% and estimated extension of membrane life for about 30%. Chemical saving from less CIP is estimated to be approximately $1,500 per year. Saving of extended membrane life from 2.0 to 2.5 years is estimated to be approximately $10,000 per year if the cost of each membrane is $600. Less CIP means less downtime and less manpower needed for conducting CIP, too. Since CIP frequency sometimes depends on other factor such as Manganese, organics or microbial contamination, review of this aspect is an ongoing service to be provided by Nalco.

4. Conclusion

For most of the industrial users, operating staff with good technical knowledge is hardly available. In order to avoid frequent operation failure and membrane damage, 3DTfM was installed at a RO system treating boiler water of a power plant and the following benefits were established:

- Target dosage of 1.8–2.2 ppm was observed for 80% of period under 3DTfM control, whereas only 6% of period achieved 1.8–2.2 ppm without 3DTfM control.
- 83% reduction of exposure at ORP > 650 mV which means better protection of membranes from oxidative damage.
- Real time warning of critical alarms to adjust dosing system or to conduct maintenance.
- 50% extension of CIP period to save cleaning chemical and to extend membrane life and operating cycle.
- Providing periodical report of normalized trends and corrective action analysis.

Due to stable chemical dosage and robust operation via monitoring and control of 3DTfM, chemical saving was estimated to be $11,500, 5,000, and 1,500 per year from less consumption of antiscalant, SBS, and CIP chemicals, respectively. Estimated saving of $10,000 per year should also be realized from extended membrane life. Customer was satisfied with the benefits delivered by 3DTfM.

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