8.5 Test with the RO Test Plant

Contents

List of Figures

1. Objective

The present study aims at evaluating the effect of soluble oil present in the pretreated oil-contaminated seawater on commercial 8 "SWRO membrane module. I this experiment performance (flux and salt rejection) of this membrane was monitored for a period of about 117 hour using the pretreated seawater obtained from oil removal unit after blending it with raw seawater.

2. Experimental Method

Equipment

The RO Test unit used in this experiment was same a described in chapter 7.3 along with its pretreatment unit.

Materials

The 8"SWRO membrane module used in this experiment was Nitto NTR 70- SWC spiral wound element.

Experimental Procedure

The performance (flux and salt rejection) of the 8"commercial SWRO membrane module was determined using pretreated oil-contaminated seawater feed after blending it with raw seawater at 1:2.5 ratio and then passing through the pretreatment unit of the RO Test Plant. The feed flow rate was maintained at 3.5 m^3/hr and pressure at 56 Kg/cm^2. The SDI was less than 3 and pH was maintained at 6.5. The oil content in the feed, brine and permeate was also determined using spectrofluorophotometer.

3. Results and Discussion

(1) Results

The results of performance (Salt rejection and permeate flow) evaluation of the 8" commercial RO module for a period of about 117 hours are given in Fig. 1 and 2. Fig. 3 shows pretreatment data of the test unit.

(2) Discussion

From the Fig.1 and 2, it is quite clear that the presence of slight amount of oil in the feed did not affect the membrane performance for a period of 140 hours. Longer period of

operation is required to ascertain whether the presence of oil in the feed affects the membrane in long time operation. From these results obtained so far it can be assumed that the present pretreatment process is adequate for the oil–contaminated seawater to be used as feed for SWRO units.

4. Conclusion

Performance evaluation of 8" commercial SWRO membrane using pretreated oil-contaminated seawater having SDI less than 3, reveals that performance of the membrane was unaffected. This suggests that the pretreatment process used in this experiment was quite effective.

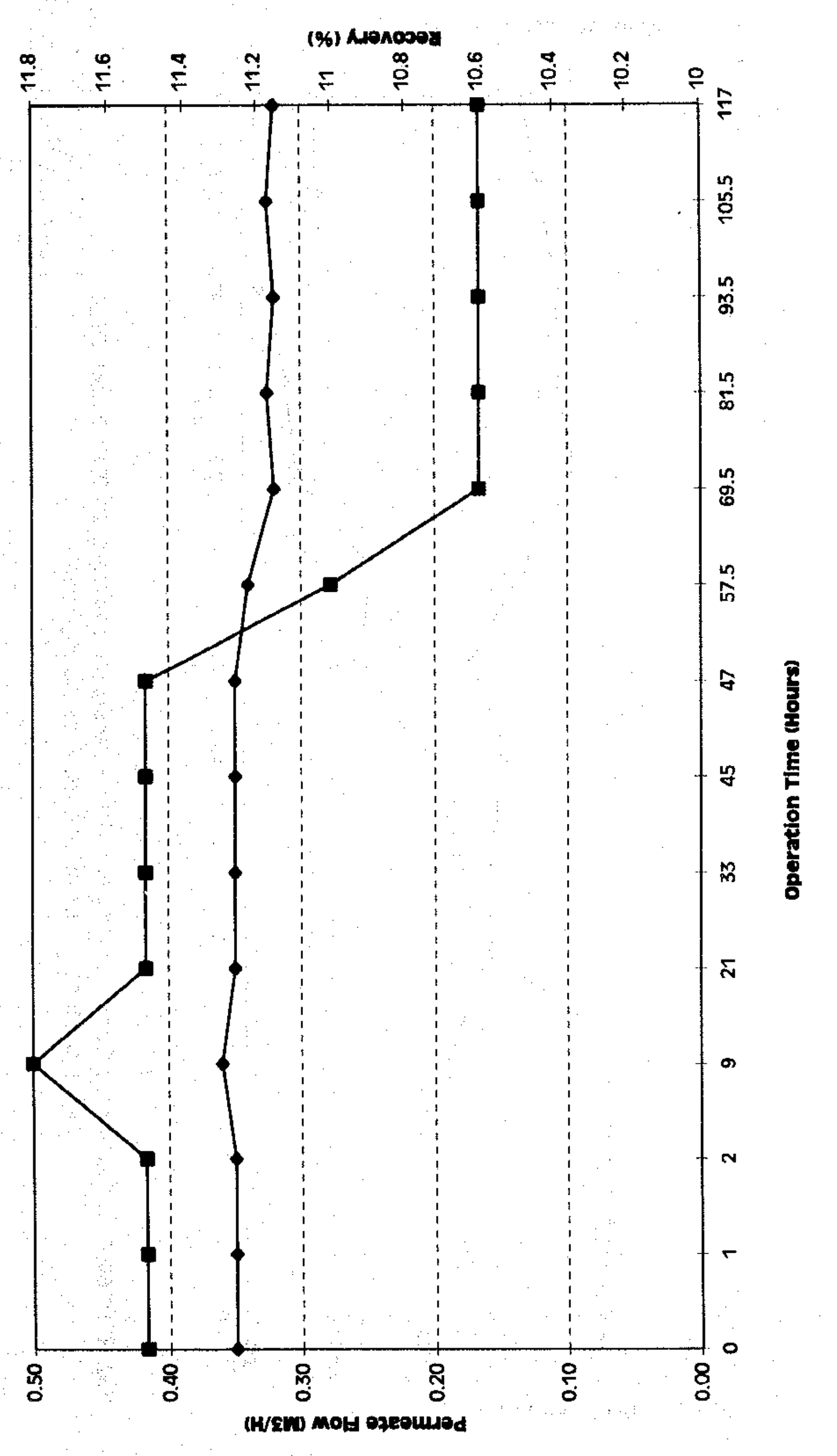

Fig. 1 Permeate Flow & Recovery for One Element Nitto Denko Membrane vs Operation Time (Feed: 0.35 ppm dissolved oil at 56 Kg/cm2)

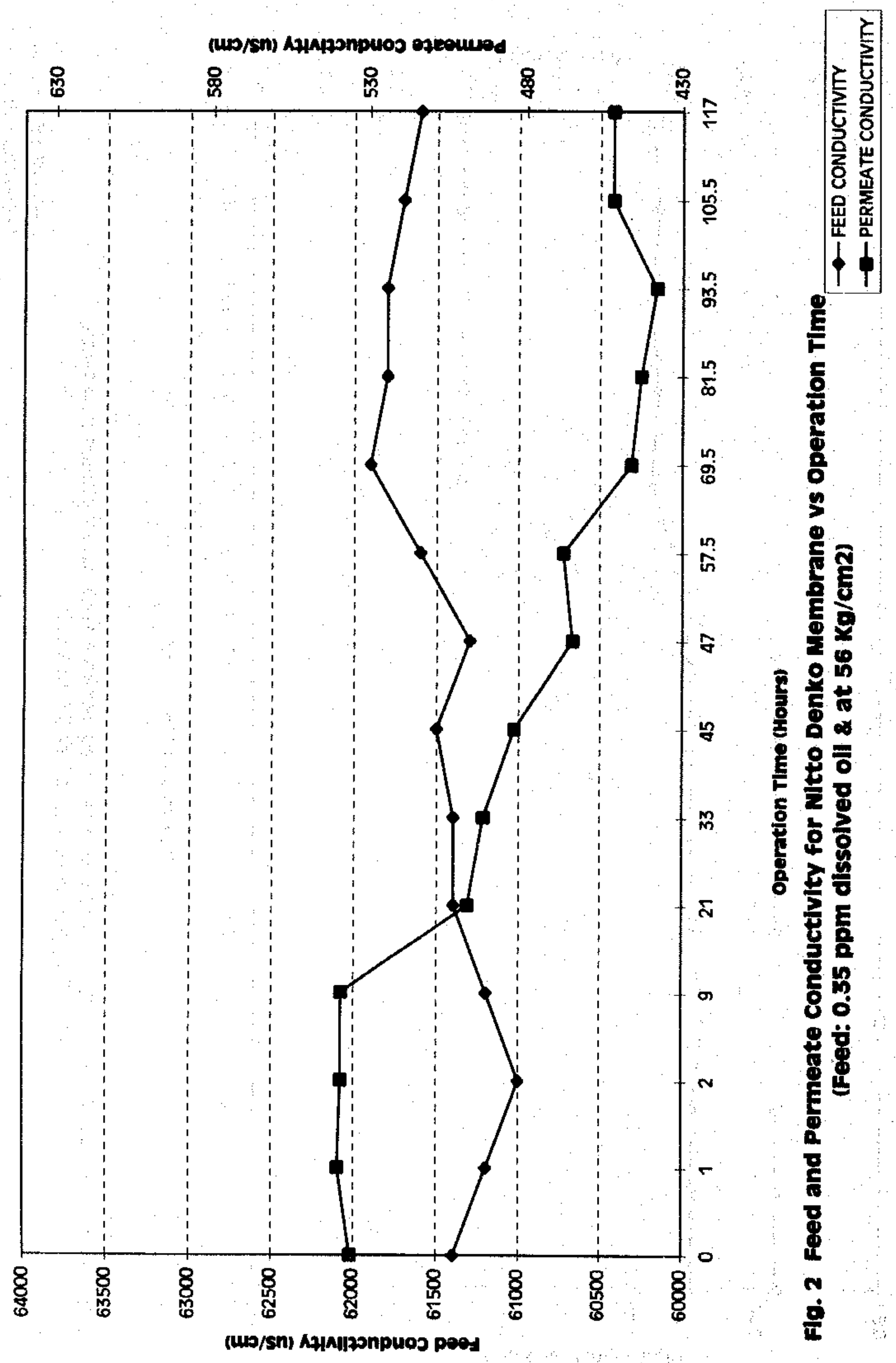

Fig. 2 Feed and Permeate Conductivity for Nitto Denko Membrane vs Operation Time (Feed: 0.35 ppm dissolved oil & at 56 Kg/cm2)

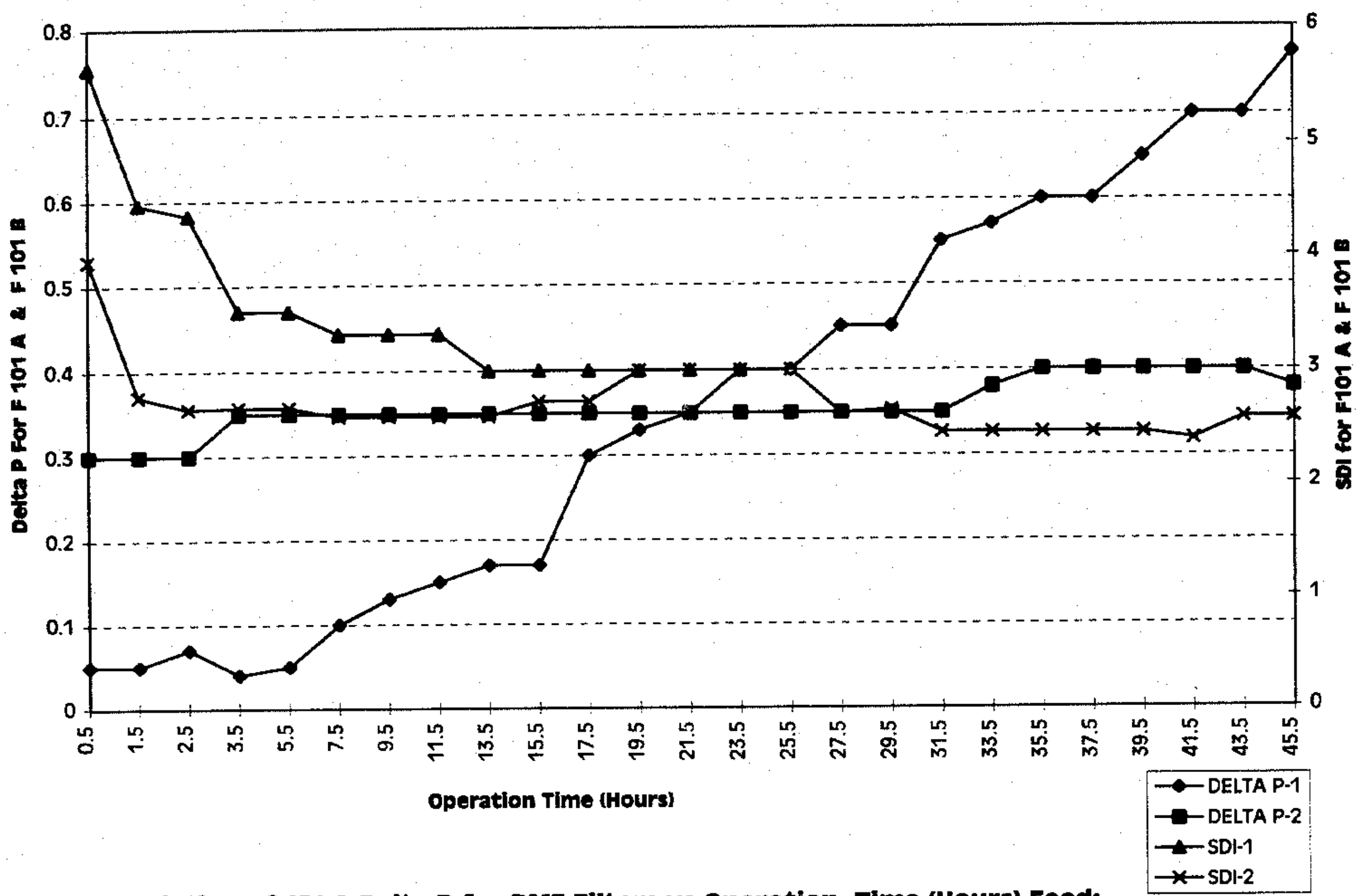

Fig. 3 Variation of SDI & Delta P for DMF Filters vs Operation Time (Hours) Feed: Oil ppm : 0.35

8.6 Transfer of Technology

Contents

List of Table

1. Objectives

Concerning research relating to measurements dealing with oil pollution in the reverse osmosis process, JICA has transferred the knowledge to the young SWCC engineers in particular Saudi engineers in the course of implementing this collaborative research.

2. Method of Implementing Technology Transfer

The main technology related to this research was broken down into the following technological elements and became the object of the technology transfer. The method of technology transfer was carried out mainly by the implementation of the collaborative research by both JICA and SWCC. This became firmly fixed through the processes of on-job-training and the preparation of written experiment reports and manuals. These techniques were prepared and supplied as substantial items for future use.

Main technological elements for the transfer of technology

1) Information concerning soluble and insoluble oil in sea water
2) Information concerning halogen compounds such as the tri- halomethanes
3) Technology of desalination pre-treatment by RO membrane
4) Pre-treatment of low concentrations of oil in sea water
5) Analysis of low concentrations of oil in sea water
6) Experimental equipment for pre-treatment
7) Effect of oil contaminated feed on membrane performance
8) Analytical equipment
9) General research activities

3. Methods and Results of Technology Transfer

(1) Information concerning soluble and insoluble oil in seawater

In addition to the training related to the various types of information which have been gathered and on-job-training in techniques for the operation and care of additionally provided analytical equipment (methods of oil analysis by fluorospectrophotometer) which were selected as a result of data surveys, analytical reports were written and analytical manuals were prepared.

(2) Information concerning halogen compounds such as the trihalomethanes

In addition to implementing analyses through on the job training based on analytical methods selected from the results of data searches, the technology was established by writing reports and the preparation of manuals.

(3) Technology of pretreatment process for RO membrane
In addition to on-job-training in the collaborative operation of the test plant, the technology was established by writing operating reports and the preparation of a plant operation manual.

(4) Pre-treatment of low concentrations of oil in sea water
In addition to on-job-training through the joint conduct of introductory laboratory scale experiments followed by experiments using a bench scale test equipment, the technology was established through the writing of reports of experiments and the preparation of plant operating manuals.

(5) Analysis of low concentrations of oil in sea water
In addition to on-job-training concerning the operation and care of the fluorophotometer used for analyzing the oil content of sea water and the writing of reports of analyses, an analytical manual was prepared.

(6) Experimental equipment for pre-treatment
In addition to on-job-training through the joint operation of the RO test plant using artificially oil-contaminated and pre-treated sea water, the technology was established through the writing of reports of experiments and the preparation of plant operating manuals.

(7) Effect of oil contaminated feed on membrane performance
The following three types of equipment for RO membrane performance testing at different scales were provided to enable membrane performance testing at each stage from a small bench scale to a full scale RO plant membranes. In addition to on-job-training through joint research activities using this experimental equipment to investigate the effect of contaminated sea-water on RO membranes, technology transfer was accomplished through report writing and the preparation of manuals, etc.

(a) Small scale, flat membrane test equipment
(b) Medium scale, mini-module type test equipment

(c) RO test plant for testing actual plant size RO module performance.

The technology has been established through the results of joint research on the use of this complete set of test equipment for measuring oil contamination from a laboratory scale to a full plant scale and it is now possible for them to implement research on measures to counter oil contamination.

(8) Analytical equipment

The following analytical equipment has been provided and the technology for its operation and maintenance has been established through teaching and the provision of manuals:

- Electron probe micro-analyzer,
- ICP emission spectrometry system,
- Infrared spectrophotometer,
- X-ray analyzer,
- Ion chromatograph and
- Fluorophotometer.

These instruments can be used for analyzing the oil content of sea-water, water quality analysis, membrane contaminant analysis, fouled membrane analysis, as well as in other general analysis conducted in a R&D desalination laboratory.

(9) Research activities

On-job-training on the experience of research activities was achieved by actually conducting experimental research methods through the joint implementation by JICA and SWCC of research activities such as data collection and analysis, research planning, conducting experiments, supervision of research processes, analysis of experimental results, preparation of data sheets, and report writing.

4. Results

The objectives, procedures and results of evaluation of technology transfer are set out in detail in Table 1.

Table 1 Transfer of Technology for RO-2

SUBJECT	OBJECTIVES	PROCEDURE	EVALUATION
OVERALL EVALUATION TECHNOLOGY FOR OIL CONTAMINATION	To improve the overall evaluation technology for oil contamination	1)To conduct experiment jointly with the trainees (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly	1)OJT traini was performed operating ①oil tolerance test of flat membrane, ②combining pretreatment equipment and mini-module, ③combining pretreatment and the RO Test Plant (Dr. Farooque and Mr. Jamalddin) 2)The result of seminar and experiment operation was reported: 8.2.2 (Dr. Farooque) 8.2.3 (Dr. Farooque) 8.3 (Dr. Farooque, Mr. Jamalddin) 8.4 (Dr. Farooque, Mr. Jamarddin) 8.5 (Dr. Farooque, Mr. Fayaz)
ANALYTICAL EQUIPMENT ON RO TEST PLANT	To improve the operation technique of following analytical equipment: 1)EPMA 2)ICP 3)INFRARED SPECTROPHOTOMETER 4)X-RAY ANALYZER 5)ION-CHROMATOGRAPH 6)etc.	1)To conduct experiment jointly with the trainees (ON-THE JOB TRAINING) 2)To prepare the report or manuals jointly	1)OJT training of operation and maintenance technology was conducted in November 1994, then operation manuals and maintenance manuals were prepared as follows: · for Electron Probe Micro Analyzer to Mr. Nausha Asrar, Mr. T. Prak Mr. Jon O'hara, Mr. Ismail, Mr. andijani, Mr. Mohd, Mr. Noor Ahmed · for ICP, Infrared spectrometer and spectrophotometer to Mr. S. Sulami, Mr. A. G. Javeed Mr. Radwan Sulaiman · for X-ray Diffractometer to Mr. Andi Jani, Mr. AFozan, Mr. Shreer · for Ion Chromatograph to Mr. S. Sulami, Dr. Nomani
GENERAL RESEARCH ACTIVITY	To study how to perform research activity	1)To conduct research activity and acquire experience by OJT method	Trainees studied the following procedure how to conduct research activity: ①Collect information(8.1.1) ②Study information obtained(8.1.1) ③Made research plan including equipment, budget, manpower, schedule experimental method(Ordinary Technical meeting held every Monday) ④Prepared materials and equipment ⑤Preparative experiment {(8.1.2), (8.2), (8.3)} ⑥Perform experiment {(8.2), (8.3), (8.4), (8.5)} ⑦Analyse the obtained results, data ⑧Prepare reports and manuals

9. Summary

Chapter 9 SUMMARY

The present project started in May, 1992 after the end of the former project. Both SWCC and JICA experts studied jointly the research themes which are required in the field of seawater desalination particularly suited for the Kingdom of Saudi Arabia, with close cooperation between both sides. JICA not only provided additional equipment and materials necessary for the present project, but also arranged and supervised installations of the MSF and RO Test Plants as well as equipment which were already provided earlier. SWCC provided the JICA experts with office rooms, accommodations, transportation of equipment and personnel, import tax exemption in order to implement their research activities smoothly. In addition to these, SWCC supplied operators most by sandis for the continuous operation of plants and utilities. A total of 4 research themes were studied under the cooperation of SWCC and JICA; 2 dealt with the MSF process and 2 dealt with the RO process:

1. Study on Scale Control for MSF Process (MSF-1)
2. Study on Countermeasures against Oil Contamination of Product Water in MSF Process (MSF-2)
3. Study on Selection of RO Membrane for Hybrid System (RO-1)
4. Study on Countermeasures against Oil Contamination for RO Process (RO-2)

Below is a summaries of the results obtained from the four research themes.

MSF-1 Study on Scale Control for MSF Process

The first step in this study was the laboratory scale experiments on how to estimate the scaling prevention capacity of scale inhibitors available in the market. Six scale inhibitors were tested in this step at various concentrations in artificially prepared brines similar to that in the Al-Jubail Phase II MSF plants. Tests were carried out at 95℃ and 110℃, where changes in residual M-alkalinity was measured along with elapsed time. It was assumed that the higher the residual M-alkalinity is, the greater is the scaling prevention capacity. The results were in good agreement with the past experience in the commercial plants, which means that the method adopted in the present study was effective and suitable for preliminary evaluation of performance of the scale inhibitors.

The next step in this study was experiments on scale inhibiting capability under conditions

closer to the actual case, that is, scaling tests with heat flux on the inner tube surface of a shell and tube heat exchanger with recirculating brine. Based on the results of the above fundamental experiments, the best among the scale inhibitors was tested in the heat exchanger. It was estimated that a scale inhibitor with the least decrease in overall heat transfer coefficient was the most effective one.

The scale inhibitor selected by the heat transfer test equipment was further tested with the MSF Test Plant (20 m^3/day). The experiments were conducted with both single scale inhibitor and scale inhibitor with acid (hybrid). The scale inhibitor used was PPN(M).

The effectiveness of the scale inhibitor was judged by the rate of change in overall heat transfer coefficient or fouling factor in the tubes. When a detectable decrease in overall heat transfer coefficient was observed; i.e. fouling factor was reached to a predetermined value, a ball cleaning was carried out, and effectiveness of ball cleaning was also studied. Summary of the results are as follows.

In case of 112℃ top brine temperature and 1.2 concentration factor, a little decease in overall heat transfer coefficient was observed up to 300 hour operation. However, in case of 1.4 concentration factor, a rapid increase in fouling factor due to scaling was observed. It was found that ball cleaning was effective for recovery of heat transfer quality; i.e. performance ratio. One had better conduct ball cleaning before a significant decrease of overall heat transfer coefficient. This fact agrees with the experience of the commercial plants.

The next is the hybrid case. In the kingdom, SCECO'S MSF plants (4,000 m^3/day x 3) at Qurayyah were operated in the past by the hybrid method. Therefore, the SWCC and JICA experts visited the plant for their reference.

In case of hybrid method, pH of brine was kept at 8.0 instead of 8.5 for the single scale inhibitor, and the concentration of added scale inhibitor was 1 mg/L against 2 mg/L for the single scale inhibitor case. In the continuous operation with 1.2 concentration factor, the decrease in overall heat transfer coefficient was almost the same as that of the single scale inhibitor. However, in the case of 1.4, a rapid decrease was observed and the decreasing rate was larger than that when using the single scale inhibitor.

As mentioned above, the joint team of SWCC and JICA were able to establish a systematic

method to evaluate the performance of scale inhibitors from laboratory scale experiments to tests conducted with the MSF Test Plant.

MSF-2 Study on Countermeasures against Oil Contamination of Product Water in MSF Process

The study consists of measurements of the distribution of organics between brine and vapor phase using a vapor-liquid equilibrium equipment, computer simulation on the behavior of pollutants in MSF plants, and pollutant addition experiments with the MSF Test Plant.

Measurements of vapor-liquid equilibrium data are classified into two; one is a homogeneous system of soluble pollutants in brine and the other is a heterogeneous system of insolubles in brine. Bromoform represents the former, and fuel oil "A" represents the latter. The evaporation mechanism of pollutants was studied with simple distillation experiments in laboratory. As a result, it was found that the heterogeneous system could be explained by a steam distillation process. Following this, the vapor pressures of pollutants was measured and their reliability was confirmed by the values in the literatures. On the other hand, it was found that the homogeneous system followed Henry's law, and therefore Henry's constants of soluble pollutants were measured.

The vapor-liquid equilibrium measurement apparatus is an equipment to measure Henry's constant directly. With this equipment, the constants of bromoform, a representative of the homogeneous system, were obtained, and the values were compared with the ones measured by the simple distillation experiments. The good agreement showed the reliability of the simple distillation experiments.

Based on the above evaporation mechanism and physical and chemical constants of water and pollutants, a computer program which simulates the behaviors of water and pollutants in MSF plants is being developed.

An additional dosing line for pollutants and sampling lines necessary for product water and brine were installed in the MSF Test Plant. Then, bromoform, a representative pollutant of homogeneous systems, was added to the feed seawater at concentrations of 0.5 mg/L or 2.75 mg/L. It was found that the behavior of water was in agreement with the computer simulation results. Most of bromoform went out of the system via ejectors. It showed that the condensation rate of bromoform was slow, and it could be considered as a noncondensable gas even if water condensed well.

When light diesel oil No.2, a representative of heterogeneous systems, was added to the MSF Test Plant at 2.5 mg/L or 10 mg/L concentration, similar trend was observed. The results show that the behavior of water can be explained by vapor–liquid equilibrium only, but those of bromoform and hydrocarbons require both equilibrium and kinetic considerations.

It is assumed that the effective prevention measures for product water pollution are to increase capacity of the vent systems including the deaerator and to improve the chamber geometry.

RO–1 Study on Selection of RO Membrane for Hybrid System

A large quantities of technical information on SWRO which is available worldwide were collected. Based on this information a computer simulation program on RO performance in a Hybrid System (MSF–RO) was conducted from which it was calculated that maximum blend ratio of RO:MSF of 1:1.5 product water would be possible using the Arabian Gulf seawater.

A SWCC/JICA team visited four RO plants (Jeddah, Umm Lujj, Duba an Haql) to make an on–site survey. Test samples of membrane elements were collected by the team and membrane autopsy and foulants analysis were conducted at SWCC–RDC and in Japan on both a Hollow Fine Fiber membrane and a Spiral Wound membrane. Oxalic acid was found to be an effective chemical cleaning method and effectively removed iron compounds. It was also able to improve membrane performance to a considerable extent.

As a result of this study, it is possible to conclude that with the equipments available at SWCC facility, we were able to find out the cause of the membrane deterioration, and with the present fine technique it should be also possible to study membrane deterioration at SWCC SWRO plant in future.

The second study dealt with membrane chlorine and turbidity tolerance. In these studies a flat membrane followed by mini–module test were conducted primarily to evaluate membrane durability. As a result of those preliminary tests it was found that slow membrane degradation is noticed in case of 0.3 ppm of residual chlorine in the feed seawater. However, it is necessary to confirm the membrane durability through longer continuous operation at lower chlorine concentration in the feed.

It was confirmed that stable service with RO membrane would be possible by feeding seawater pretreated using dual media filtration and dosing a coagulant.

Finally, performance test of RO plants with three commercial size SWRO membrane modules were conducted. Those membrane modules were tested utilizing two independent skid mounted RO units that received filtered water from dual media filter with a capacity of $168m^3/d$.

It was found that dosage of 1.0 – 1.3 ppm of Fe^{+3}, produced a feed water with SDI less than 4.0 which meets the specifications requirement of the two hollow fine and spiral wound membranes.

Permeate conductivity for three commercial size Japanese-made SWRO membrane modules (NITTO DENKO, TOYOBO, TORAY) were 250 – 750 μS/cm. It was confirmed that this high quality of permeate can be obtained and maintained constant at applied pressure of $56kg/cm^2$.

It is important to confirm the stability of the system in order to be adopted in the actual plant. Further tests to confirm the stability of the membrane and the quality of the product water in long term period utilizing the testing method established by this cooperative research are recommended.

RO-2 Study on Countermeasures against Oil-contamination for RO Process

This research aims at establishing a method of operation RO seawater desalination plants safely even if the feed seawater is contaminated with oil.

The first step was to review analytical methods of oil and trihalomethane measurement in seawater in order to establish a sensitive analytical procedure for the measurements of those contaminants at low concentrations. After trial of several analytical methods, success was achieved by using spectrofluorometric and GC-MS method.

Earlier experiments were conducted using flat sheet membrane to evaluate their tolerance to oil present in the oil-contaminated seawater. Then, the research was proceeded to mini–

module tests. At the stage, it became apparent, as expected, that the long term membrane test with combination of pretreatment system of oil-contaminated seawater is important.

A specially designed pilot plant was used for preparing the oil-contaminated seawater and for its removal from the feed by coagulation and filtration. The oil-contaminated seawater was artificially prepared by dispersing oil with high reproducibility.

By using this artificially oil-contaminated seawater, it was confirmed that the oil can be removed by the Fe^{+3} coagulation followed by sand filtration. Polymer and anthracite also showed good oil removal performance.

Nearly all the oil are removed by the coagulation-filtration process, with only traces of less than 0.5 ppm remaining in the feed. The filtrate was fed to an 8" commercial membrane modules. Plant performance were steady and unaffected by the presence of oil residue in the feed. Furthermore, no oil can be detected in the permeate. From these important results it can be concluded that the present coagulation-filtration pretreatment process is adequate for oil removal at the above level and is not affecting the membrane performance.

The testing procedure of the pretreatment of the oil contaminated seawater and 8" membrane module has been established by this cooperative research work. Further testing is recommended to confirm the above finding and to determine if the stability of the system will be maintained after long term operation by using the testing method.

As described above, we have almost achieved our purpose of the four research themes. However, it was impossible to confirm the stability or the deterioration of the system in course of time which requires long run operations since the time was limited. As the testing equipments and technologies have been established in SWCC, we are expecting the future progress in those field.

All the research themes in the project are the most up-to-date, and the researches have been conducted from fundamentals to applications, systematically and in a well-organized manner with close cooperation between SWCC and JICA. Consequently, the obtained results are to attract much attention in the world of desalination technology. In addition, it should be emphasized that this project was carried out from user's viewpoint, that is to optimize the use of the existing plants, to estimate manufacturer's proposals and to solve environmental problems while most of the past researches were done from manufacturer's

viewpoint. We are proud of our achievement as the first milestone, and confident of future success.