

# High TBT (85°C) MED Technology Development



Osman A. Hamed, Khalid Bamardouf, Abdulaziz S. Al-Jamhan, Faisal A. Abu Derman  
Desalination Technologies Research Institute (DTRI)  
Saline Water Conversion Corporation (SWCC)



Younggeun Lee\*, Amr M. Ahmed, Byungsung Park, Seungwon Ihm  
Doosan Water R&D Center Dammam, KSA

# TABLE OF CONTENTS



## **INTRODUCTION TO DOOSAN WATER**

### **BUSINESS GROUPS**

### **WATER BUSINESS IN DOOSAN**

## **HT MED TECHNOLOGY DEVELOPMENT**

### **INTRODUCTION**

### **PREVIOUS STUDY IN KOREA**

### **JOINT DEMONSTRATION IN KSA**

### **CONCLUDING REMARKS**

# DOOSAN HEAVY INDUSTRIES & CONSTRUCTION

At Doosan Heavy Industries & Construction, our vision is to be a global leader in power and water, and we are committed to helping our clients meet tomorrow's challenges and opportunities.



**Global Leader**  
in power  
and water



**Front Runner**  
in industrial  
plants



**Boost**  
in global business  
competencies



**Renewable Energy**  
for our future

- Revenue: US\$18.1 billion
- Employees: 8,200

(2014 figures / Locally hired employees excluded)

## NUCLEAR



## EPC



## WATER



## POWER



## CASTING & FORGING



**Doosan  
Skoda Power**



**Doosan  
Lentjes**



**Doosan  
Babcock**



**Doosan  
IMGB**



**Doosan  
Power  
System India**



**Doosan  
Enpure**



**Doosan  
Hydro  
Technology**



**Doosan  
VINA**



# DESALINATION TECHNOLOGIES

## MSF (MULTI-STAGE FLASH)

Large-scale unit, one-module fabrication, and hybrid solution

## MED (MULTI-EFFECT DISTILLATION)

High TBT MED-TVC

## RO (REVERSE OSMOSIS)

World's largest RO train with application of 16-inch membranes

### [Ras Al Khair Ph.1 Hybrid] KSA



#### World's Largest Desalination Plant with Hybrid Config. (MSF + RO)

- Capacity : 228MIGD (1,036,488m<sup>3</sup>/day)
- Location : Ras Al Khair, Saudi Arabia
- Client : Saline Water Conversion Corporation (SWCC)
- Evaporator Unit Capacity : 20MIGD (90,920m<sup>3</sup>/day)
- Configuration : 20 MIGD x 8 units
- Performance Ratio : 9.5
- Dimensions(m) : W118.8 x L24.3 x H11.4

### [Yanbu Ph.2 Exp. MED] KSA



#### World's Largest Multi-Effect Distillation (MED) Distiller

- Location : Yanbu, Saudi Arabia
- Client : SWCC
- Distiller Unit Capacity : 15MIGD (68,190m<sup>3</sup>/day)
- Configuration : 15 MIGD x 1 unit
- Gain Output Ratio : 9.7
- Delivery : 18 months

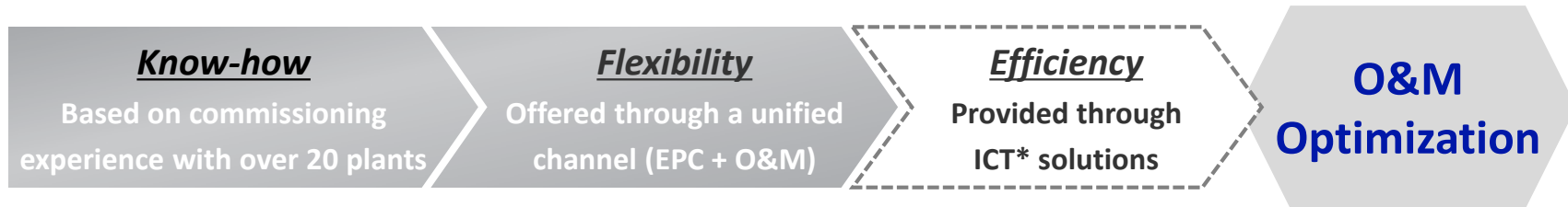
### [Escondida Water Supply] Chile



#### Largest Desalination Plant in South America

- Capacity : 47.5MIGD (215,935m<sup>3</sup>/day)
- Pretreatment : Pressurized DMF
- Configuration : 5.3MIGD x 9 trains
- Feed water TDS : 39,300 mg/L
- Product water TDS : < 700 mg/L
- Client : Minera Escondida (BHP Billiton)
- Currently delivering the project for the world's largest copper mining operation

# OPERATION & MAINTENANCE



## [Shuwaikh RO] Kuwait



### Kuwait's First SWRO Desalination Plant

- Capacity : 30MIGD (136,380m<sup>3</sup>/day)
- Pretreatment : DAF+UF
- TDS : 45,000 mg/L
- O&M Period : 3 years ('11.10~'14.10)
- Client : **Ministry of Electricity & Water**
- Challenging conditions including frequent red tides events and high TDS

## [Ras Al Khair Ph.1] Saudi Arabia



### World's Largest Desalination Plant (Hybrid (MSF+RO))

- Capacity : 228MIGD (1,036,488m<sup>3</sup>/day)
- Pretreatment : DAF+DMF+Cartridge filters
- TDS : 45,000 mg/L
- O&M Period : 6 years ('13.12~'19.4)
- Client : **SWCC**
- Simultaneous service for both thermal (MSF) and SWRO plants

## [Busan Gijang RO] Korea



### Korea's First Large-scale Desalination Plant

- Capacity : 10MIGD (45,460m<sup>3</sup>/day)
- Pretreatment : DABF+UF/DABF+DMF+C.F.
- TDS : 34,500 mg/L
- O&M Period : 20 years ('14.7~'34.6)
- Client : **Busan Metropolitan City**
- Service for the world's largest capacity RO train (8MIGD) with 16-inch membranes



# TABLE OF CONTENTS



## INTRODUCTION TO DOOSAN WATER

### BUSINESS GROUPS

### WATER BUSINESS IN DOOSAN

## HT MED TECHNOLOGY DEVELOPMENT

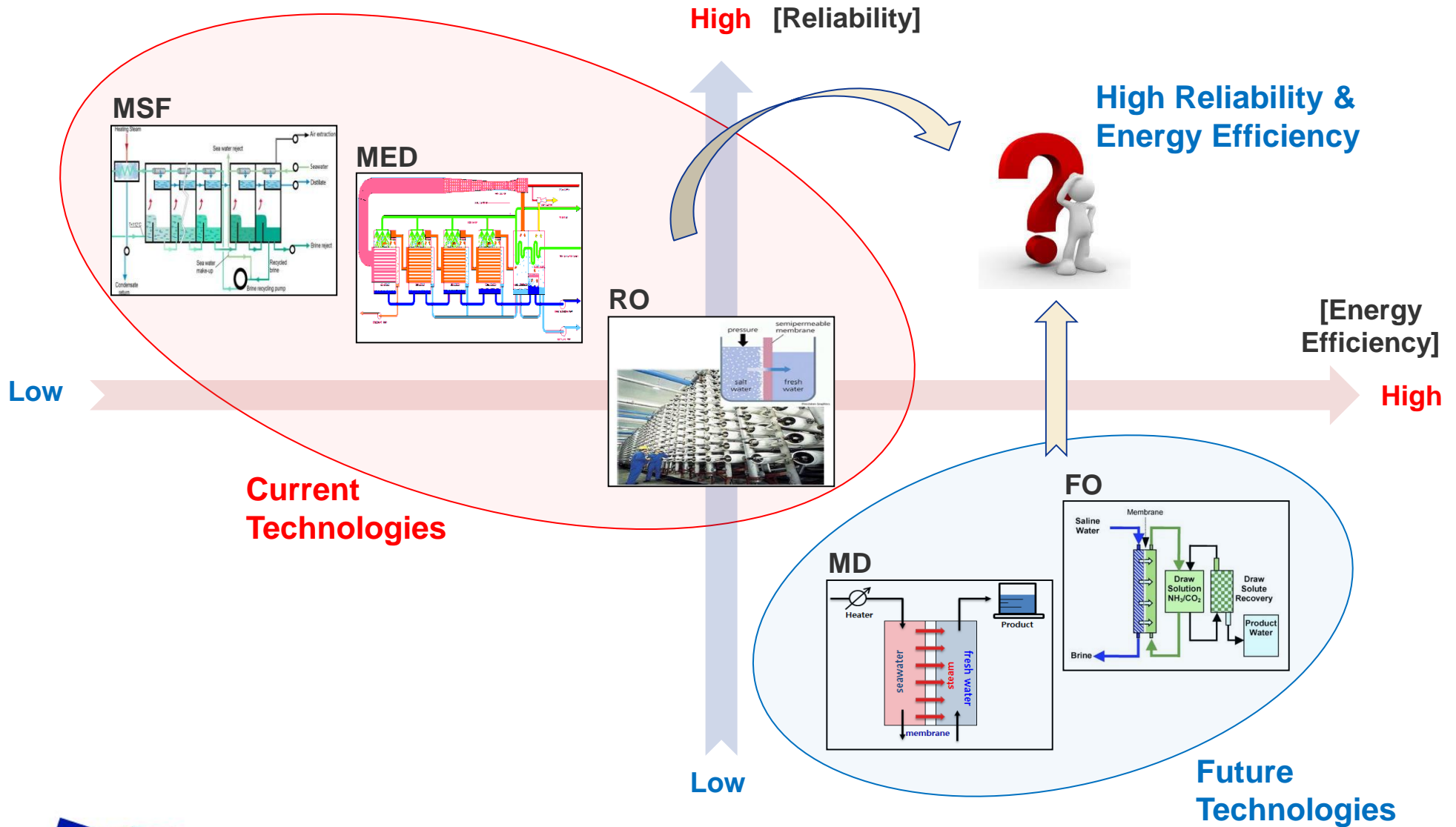
### INTRODUCTION

### PREVIOUS STUDY IN KOREA

### JOINT DEMONSTRATION IN KSA

### CONCLUDING REMARKS

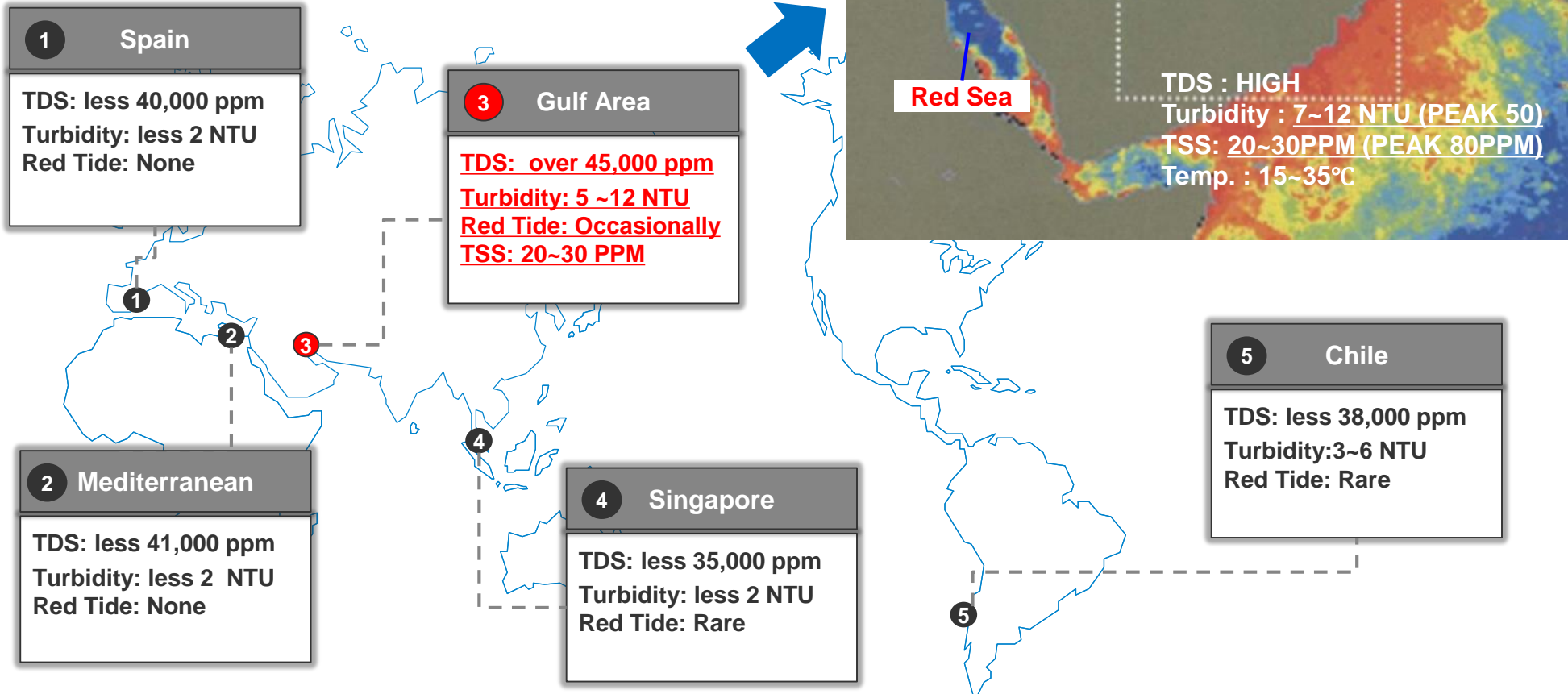
# INTRO... Desalination Technology






# COMPARISON FOR SEAWATER CONDITION

Seawater condition in Gulf area is much worse than any other region.



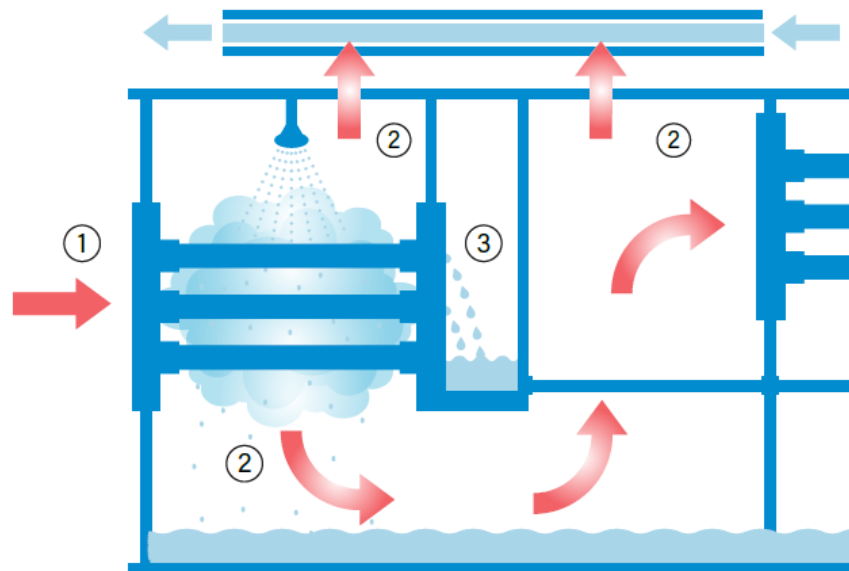
# DIFFICULTIES FOR SWRO IN GULF AREA

	<u>Gulf Area</u>	<u>Difficulty</u>	
Salinity (TDS, ppm)	<ul style="list-style-type: none"><li>• Highest salinity in the world (45,000ppm)</li></ul>	<ul style="list-style-type: none"><li>• <b>Recovery ratio</b> to be decreased</li><li>• Shorten <b>life time of membrane</b></li></ul>	 <ul style="list-style-type: none"><li>✓ High CAPEX for sufficient pretreatment</li><li>✓ Low recovery ratio</li><li>✓ Low reliability</li><li>✓ High O&amp;M Cost</li></ul>
Turbidity (NTU)	<ul style="list-style-type: none"><li>• 5~12 NTU</li><li>• Peak 50 NTU</li></ul>	<ul style="list-style-type: none"><li>• <b>Conservative pretreatment</b> design to be required (2~3 stage)</li></ul>	
TSS (Total suspended Solid, ppm)	<ul style="list-style-type: none"><li>• 20~30 ppm</li><li>• Peak 80 ppm</li></ul>	<ul style="list-style-type: none"><li>• <b>Conservative pretreatment</b> design to be required (&lt; 5ppm)</li></ul>	
Red Tide	<ul style="list-style-type: none"><li>• Occasionally</li></ul>	<ul style="list-style-type: none"><li>• Reliability to be decreased sharply</li><li>• <b>DAF</b> is essential system</li><li>• Beach well can be required.</li></ul>	

# INTRODUCTION: MED TECHNOLOGY

Multi-Effect Distillation (MED) is an advanced form of thermal desalination now playing a major role in large-scale desalination projects with the higher efficiency.

## How It Works

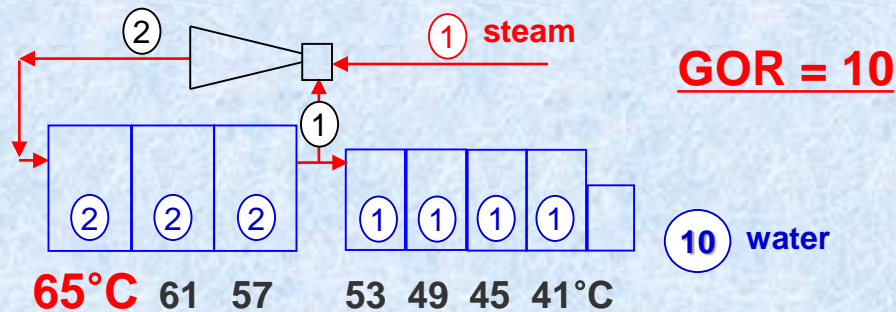


- ① Steam passes through the inside of the tubes
- ② Seawater is sprayed onto the outside of tube, generating vapor which is moved to next effect to be used as the heat source
- ③ Vapor condenses inside of the tube and is collected as fresh water

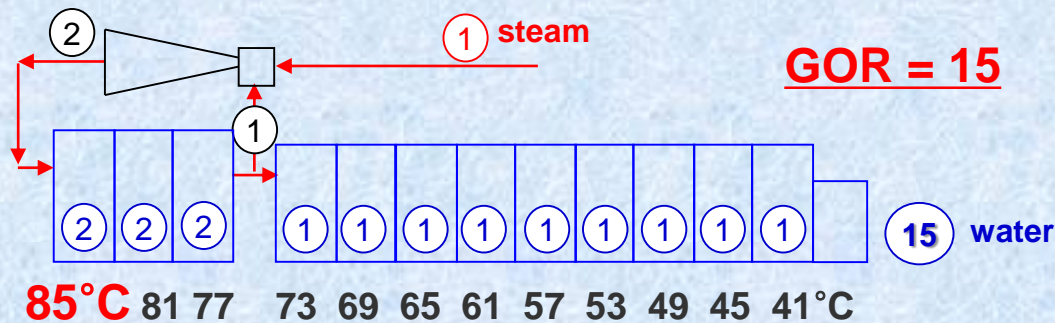
# INTRODUCTION: BENEFITS OF ADVANCED HT-MED

Increasing TBT 65 → 85°C allows 50% increase in MED efficiency (GOR\* & PR\*\*).  
 = ~33% Steam Saving to produce the same amount of water

Typical MED: **10kg Water** from 1kg Steam



New HT MED: **15kg Water** from 1kg Steam



**33% less energy**  
to produce same water

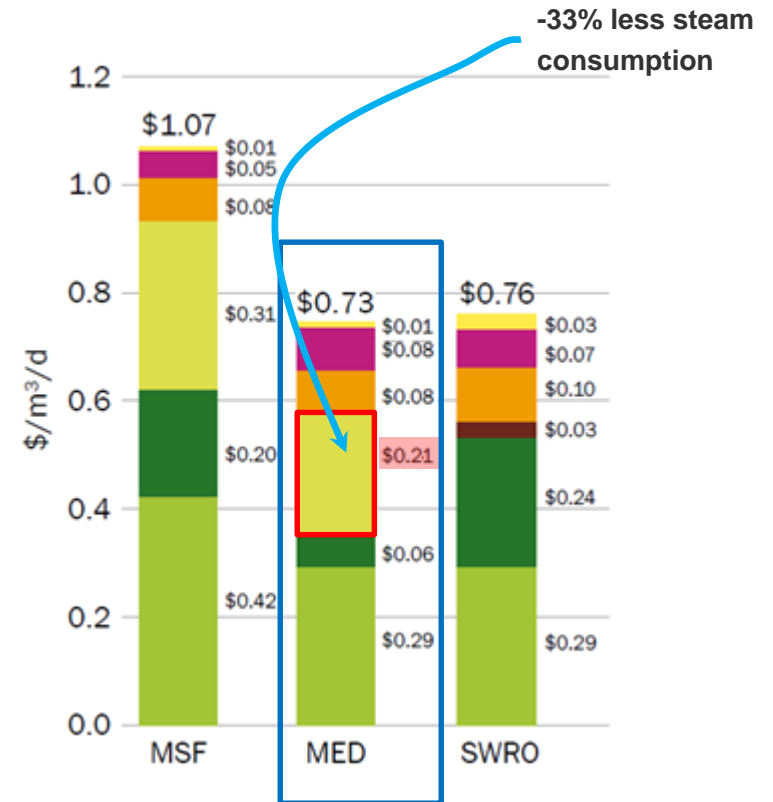
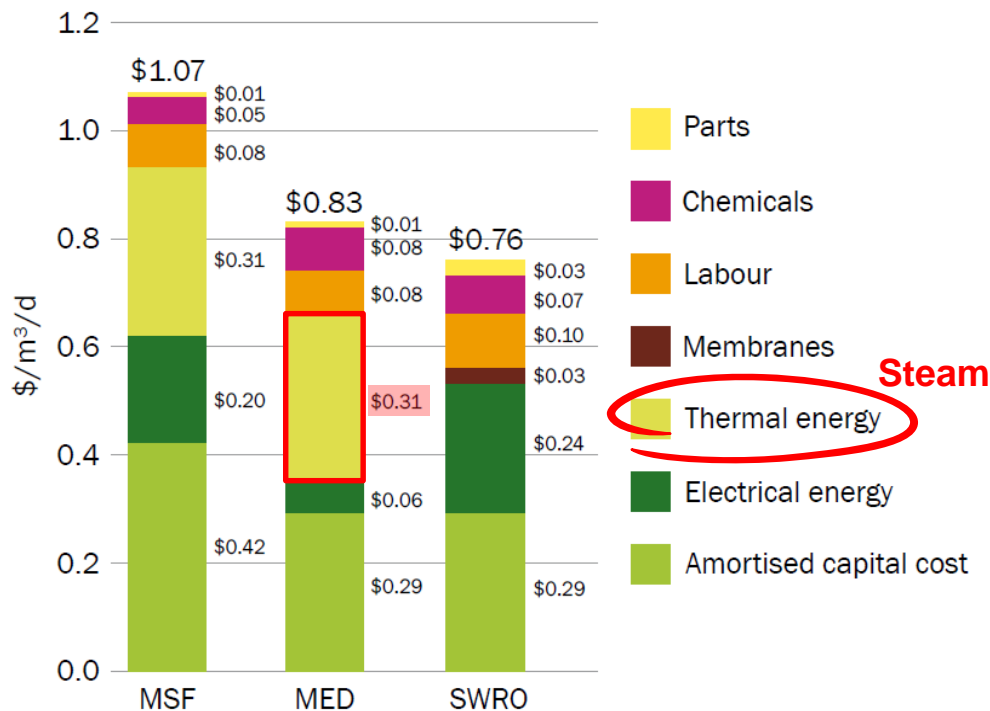


# INTRODUCTION: BENEFITS OF ADVANCED HT-MED

Energy cost is a huge portion in desalting seawater.

Saving steam consumption in HT-MED reduces the water production cost of MED.

Relative operating costs of the main desalination process

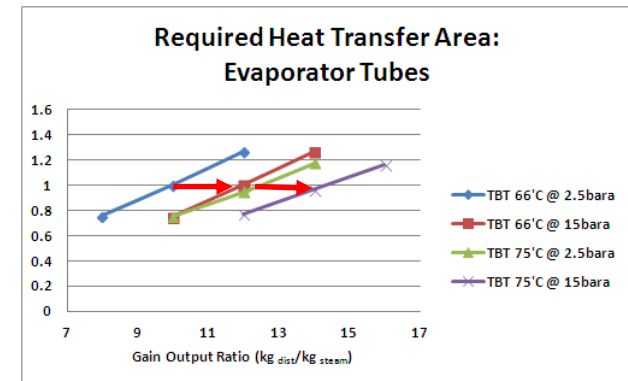
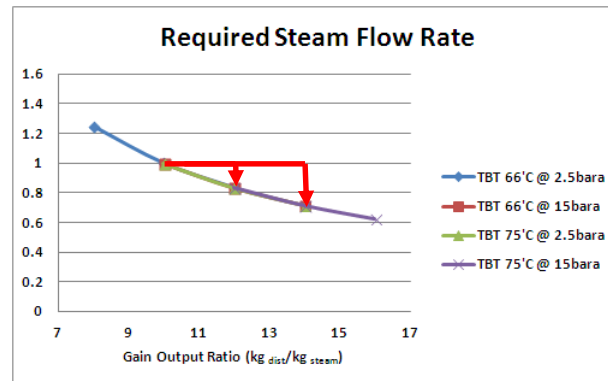
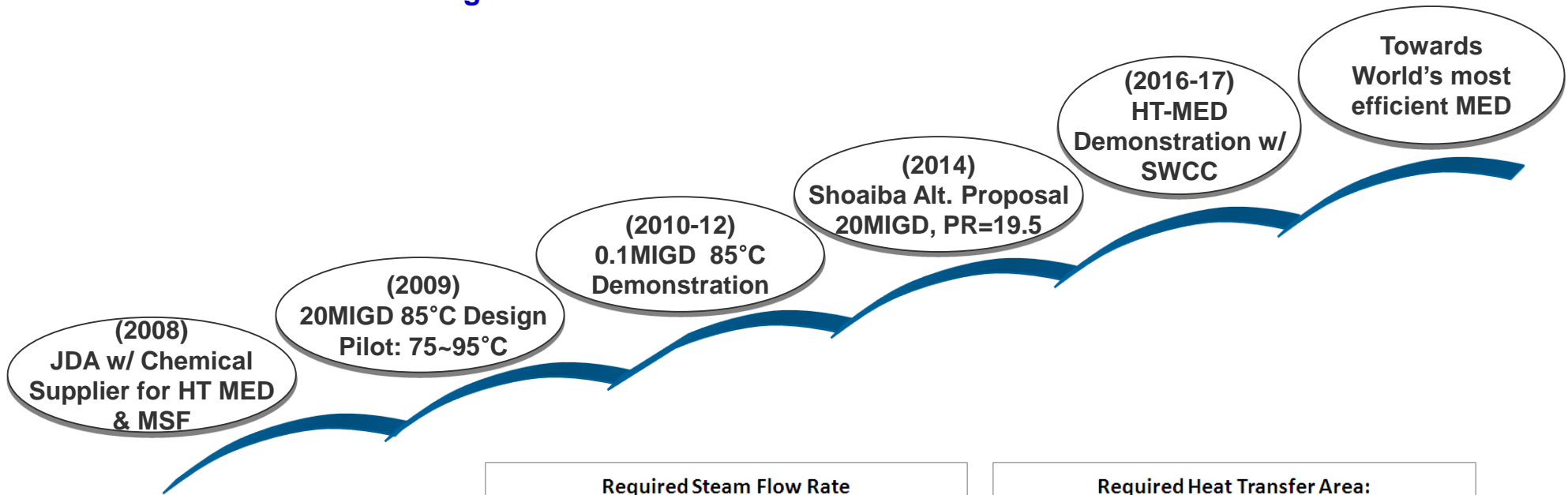


Global Water Intelligence, Vol. 11, Issue 9, Sep. 2010, p. 8



# MED-TVC TECHNOLOGY DEVELOPMENT

- © High Performance (PR 10 → 15+) MED
  - Breakthrough in MED EFFICIENCY (by 50+%)
  - : Steam & Seawater Saving 30+%



# PREVIOUS STUDY: 24 ton/day Pilot

[2008-2009] 24 ton/day Pilot in Korea - precise experiments for different conditions  
 : TBT 85°C is targeted after 29 experiments for 75~95°C



No. of Exp.	TBT (°C)	Steam T (°C)	Feed Flow Rate (kg/hr)	Test Period	A-Sc. Type*	A-Sc. Desins (ppm)	Anti-Foam (ppm)	Date of Exp.	Remarks
29	85	89.3	700	24 hrs	N/A	0	0.15	Jan. 26~27 '10	TDS=64,000ppm
28	85	88.7	700	14 days	206	0.5	0.15	Dec. 11~24	TDS=64,000ppm
27	85	89.4	700	48 hrs	206	1	0.15	Dec. 1~3	TDS=64,000ppm
26	85	89.4	700	48 hrs	N/A	0	0.15	Nov. 24~26	TDS=64,000ppm
25	85	88.7	700	48 hrs	206	1	0.15	Nov. 19~21	TDS=64,000ppm
24	85	89	700	48 hrs	N/A	0	0.15	Oct. 28~30	TDS=64,000ppm
23	85	89.9	700	48 hrs	N/A	0	0.15	Oct. 20~22	TDS=64,000ppm
22	85	88.9	700	48 hrs	206	0.5	0.15	Oct. 12~14	TDS=64,000ppm
21	85	90.2	700	48 hrs	206	2	0.15	Sep. 15~17	TDS=64,000ppm
20	85	90.2	700	24 hrs	206	4	0.15	Sep. 9~10	TDS=64,000ppm
19	85	87.5	700	24 hrs	206	0.5	0.15	Aug. 28~27	TDS=64,000ppm
18	85	87.4	700	48 hrs	N/A	0	0.15	Aug. 19~20	TDS=64,000ppm
17	85	87.3	700	96 hrs	206	0.5	0.15	Aug. 10~14	TDS=64,000ppm
16	85	91.6	700	48 hrs	202	0.5	0.15	July 28~30	Anti-Scalant Testing
15	85	89	700	48 hrs	206	1	0.15	July 20~22	
14	85	89.5	700	48 hrs	N/A	0	0.15	July 13~15	
13	85	89.4	700	48 hrs	206	0.5	0.15	June 29~July 1	
12	85	88.3	700	48 hrs	206	0.5	0.15	June 22~24	
11	85	88.3	1100	48 hrs	202	1	0.15	June 15~17	Heat Transfer Testing
10	85	89	1100	48 hrs	202	1	0.15	June 8~10	
9	75	77.5	1100	48 hrs	202	1	0.15	June 2~4	
8	75	77.1	700	48 hrs	202	1	0.15	May 25~27	
7	85	91.9	700	48 hrs	202	1	0.15	May 18~20	
6	85	87.5	900	48 hrs	202	1	0.15	May 11~13	
5	85	87.9	700	48 hrs	202	2	0.15	Apr. 27~29	
4	75	78.3	900	48 hrs	202	2	0.15	Apr. 20~22	
3	85	98.5	900	48 hrs	202	2	0.15	Apr. 6~8	
2	85	88.7	900	48 hrs	202	2	0.15	Mar. 16~18	
1	85	87.6	970	24 hrs	202	2	0.15	Feb. 22~24 '09	No A-Sc. during first 15 hrs



2008~2009



- ✓ 29 experiments
  - ✓ Feed TDS up to 64,000ppm (MENA tube bundle bottom)
  - ✓ Temperature: 75~95 °C
  - ✓ Feed flow: 700~1,100 kg/hr
  - ✓ New chemicals tested
- TBT 85 °C achievable!!

# PREVIOUS STUDY: 410 ton/day Pilot Demonstration

[2010~2012] Demonstration of TBT 85°C MED-TVC with industrial-size pilot (410 ton/day) in Korea



- TVC performance test
- Feed optimization test
- Anti-scalant dosage rate test
- Long term operational demonstration

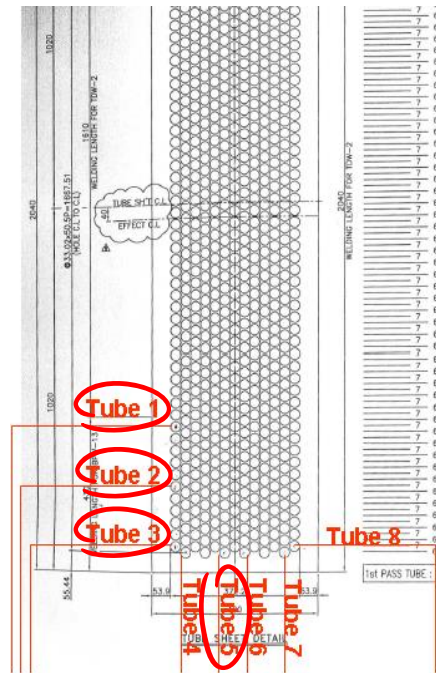
## ● 0.1MIGD High Temperature MED-TVC with Brine-Recirculation

- Top Brine Temperature: 85°C
- Bottom Brine Temperature: 67°C
- Sea water intake: 30~40 (ton/hr), 20°C, 27,000~32,000 ppm
- Total feed water supply: 60~70 (ton/hr), 65°C, 45,000~53,000 ppm
- Distillate production: 17 t/h = 0.1 MIGD (410 t/d)



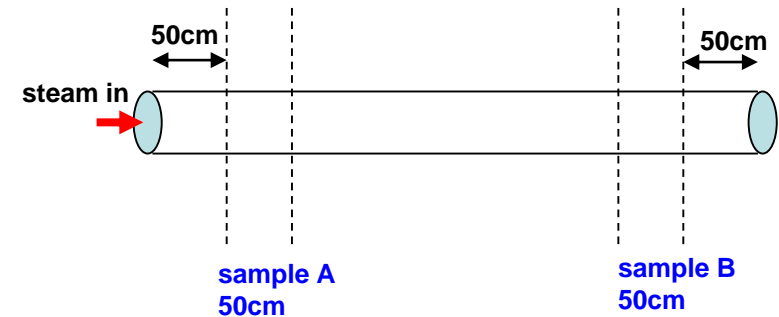
# PREVIOUS STUDY: 410 ton/day Pilot Demonstration

At the end of each experimental case, tubes were sampled and shipped to A/S Supplier for further analysis.



## Sampling Tubes

- 1st Effect: #1~5, 7
- 2nd Effect: #1~3, 5
- 5th Effect: #1~3, 5

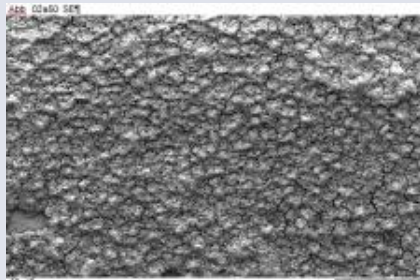


→ A/S Supplier: Scale Analysis with AAS, SEM, XRD



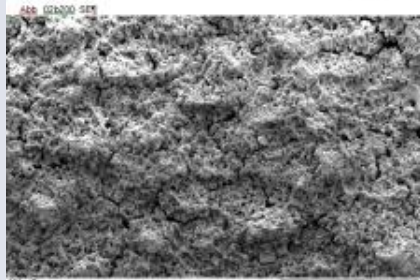
# PREVIOUS STUDY: 410 ton/day Pilot Demonstration

As a result of chemical composition analysis, it was shown that soft scale was dominant in the scale deposition as an amorphous species.



## ► SEM

- Coupon surface totally covered with a thin scale layer



## ► XRD

- Indicates that scale is only based on amorphous species

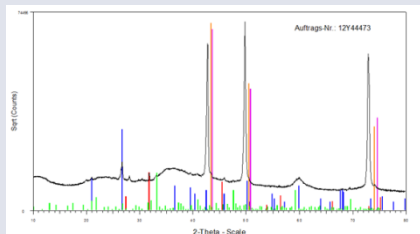
## SOFT SCALE

## ► AAS (Tube)

- scale detected in Effect #1

- very low scale detected in Effect #2

- very low scale detected in Effect #5



# JOINT DEMONSTRATION WITH SWCC-DTRI

## ● Signing Ceremony for HT MED Collaboration Project



< Signing Ceremony >

- Date: 7<sup>th</sup> Feb, 2016
- Collaboration Period  
: 3 years (2016 ~ 2018)
- Collaboration Target
  - Demonstration of High Temperature (TBT 85°C) MED-TVC at Gulf Water condition with DTRI(SWCC)

# JOINT DEMONSTRATION WITH SWCC-DTRI

## ● DTRI MED Pilot



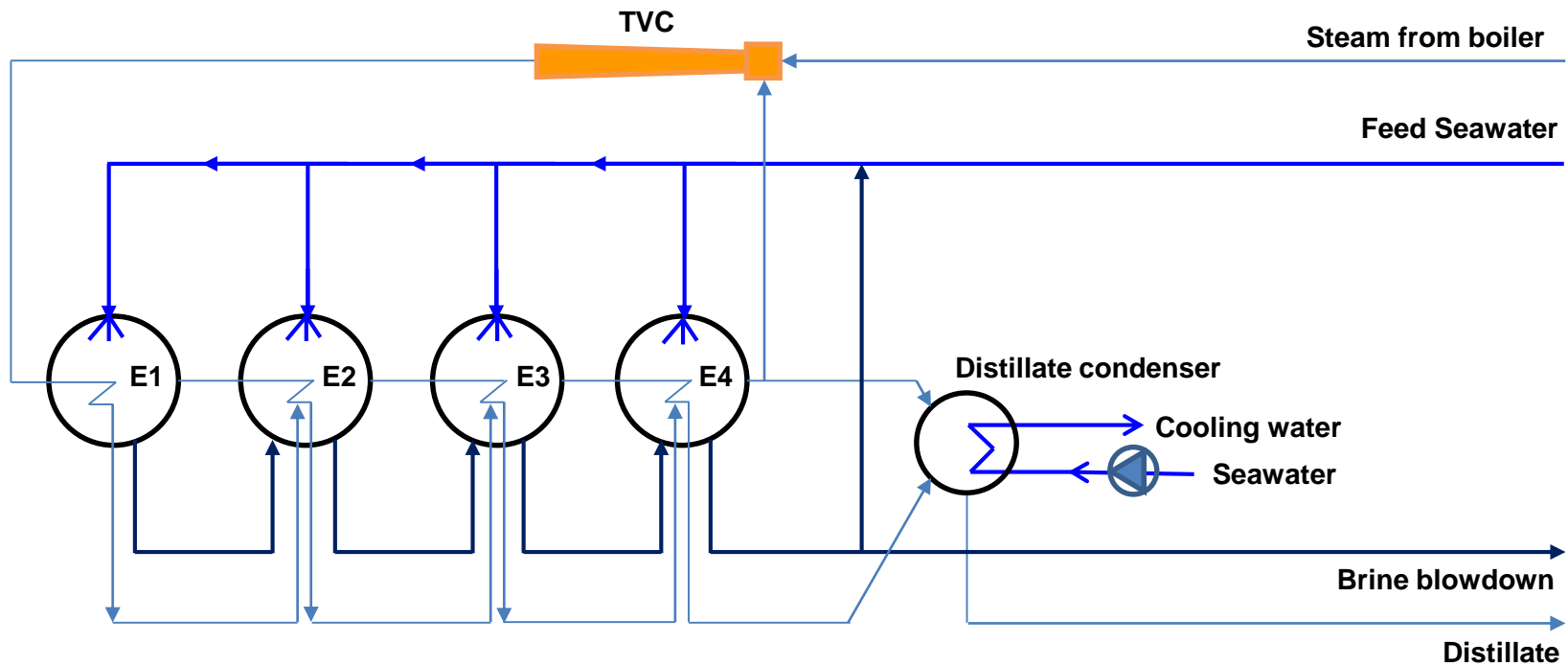
### **DTRI MED Pilot**

- Location: DTRI in Jubail
- Capacity: 1.3 ton/hr
- Type: Brine Recirculation MED-TVC
- No. of Effect: 4
- Tube Material: Titanium
- No. of Pass: 2
- Feed Type: Tray + Perforated plate

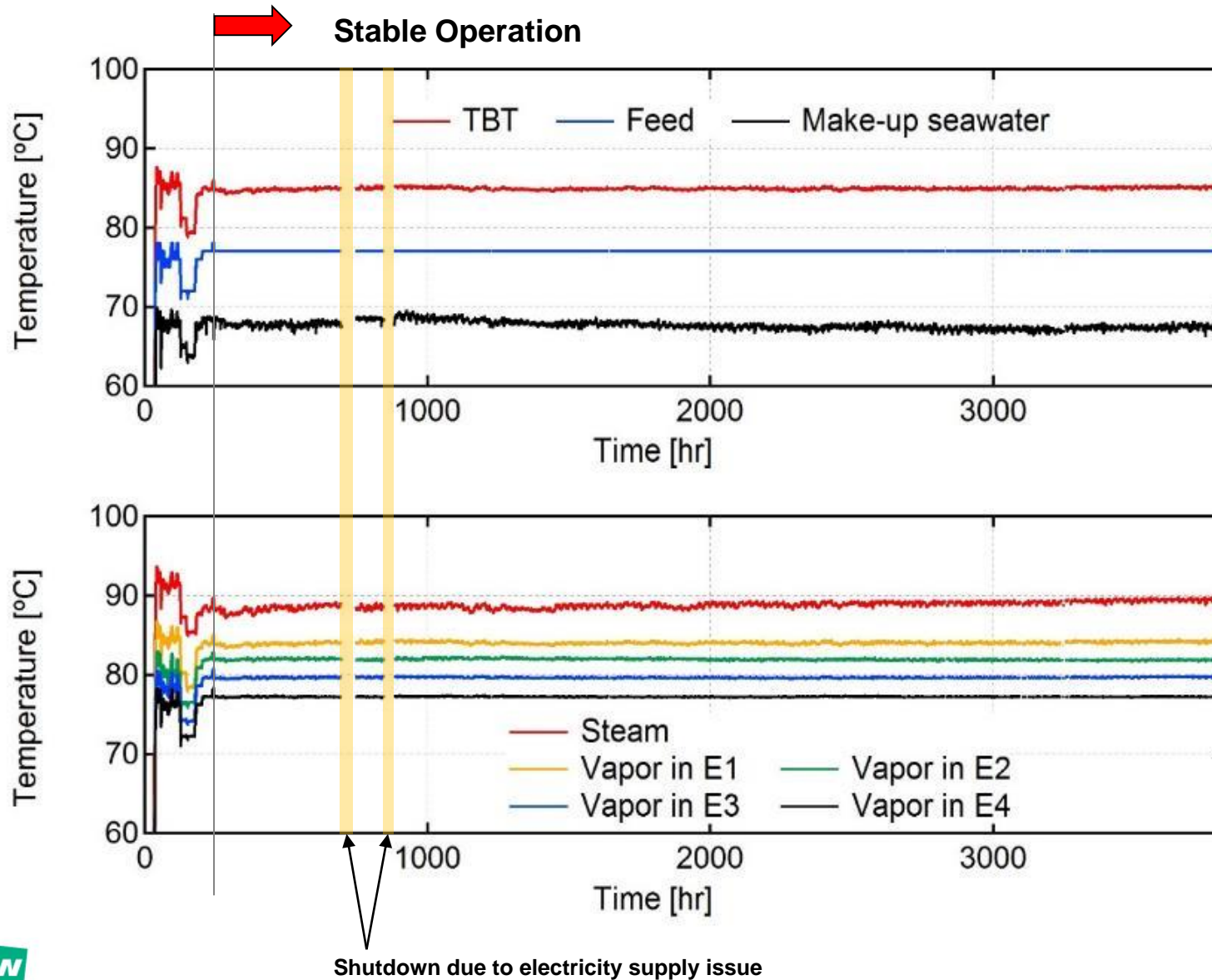
## ● Operating Condition of 5 Months Scale Test

- Top Brine Temperature: 85°C
- Bottom Brine Temperature: 78°C
- Total feed water supply: 35 ton/hr, 60,000~63,000 ppm
- Distillate production: 1 ton/hr

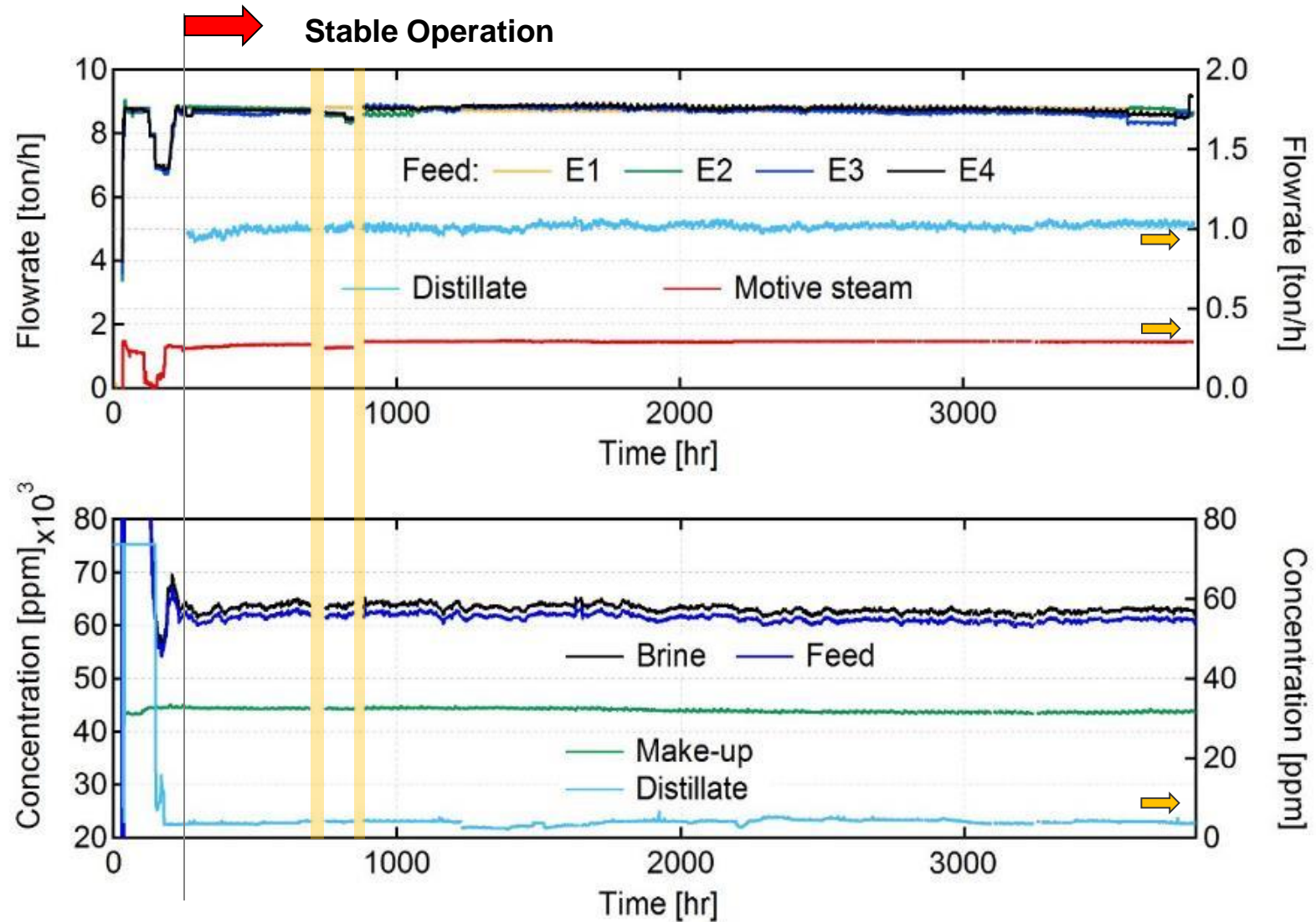
## ● MED Pilot Schematic Diagram



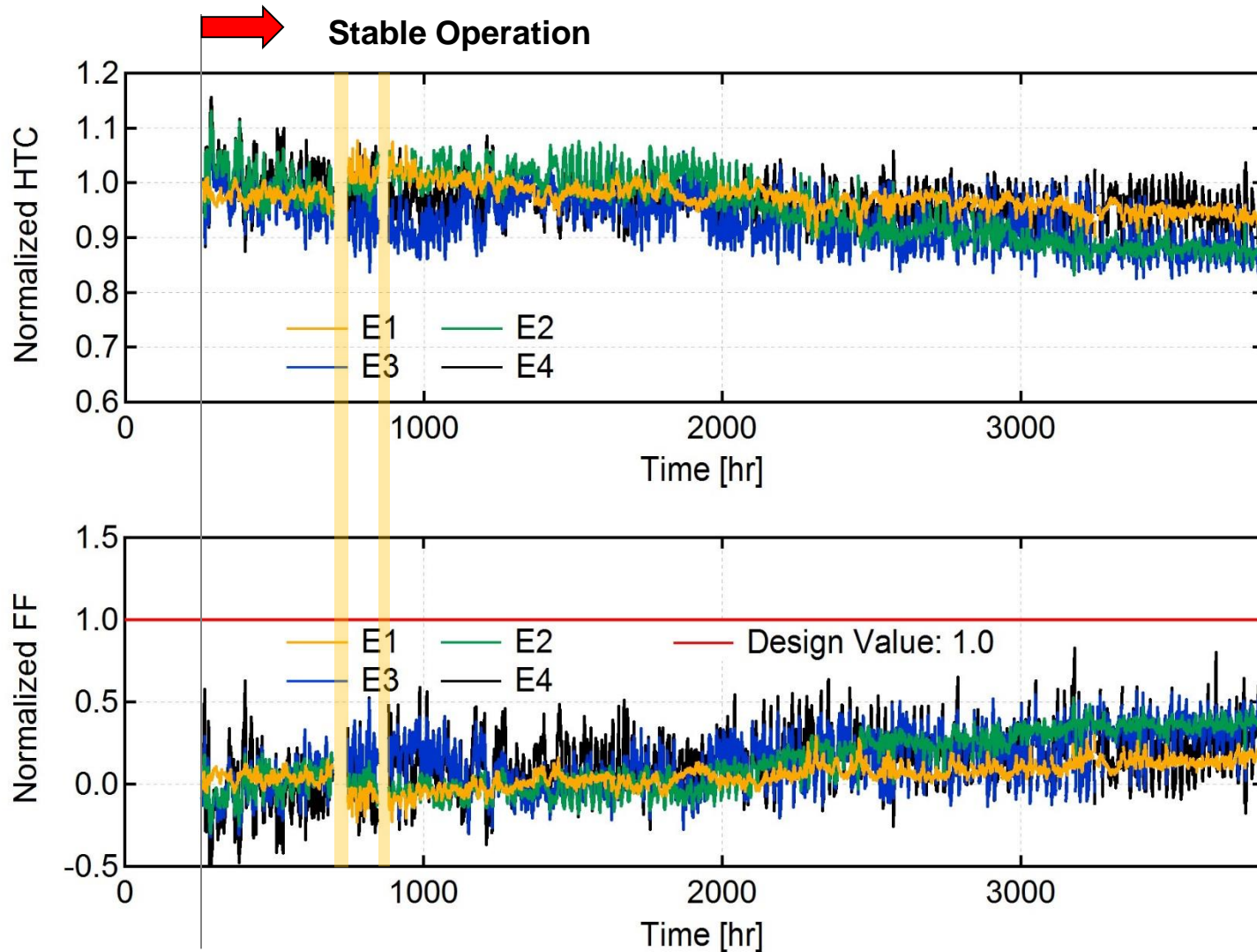
# OPERATION DATA : TEMPERATURE PROFILE



# OPERATION DATA: FLOWRATE & CONCENTRATION PROFILE



# FOULING FACTOR ANALYSIS: HTC\* & FF\*\* PROFILE



\*HTC, Heat transfer coefficient

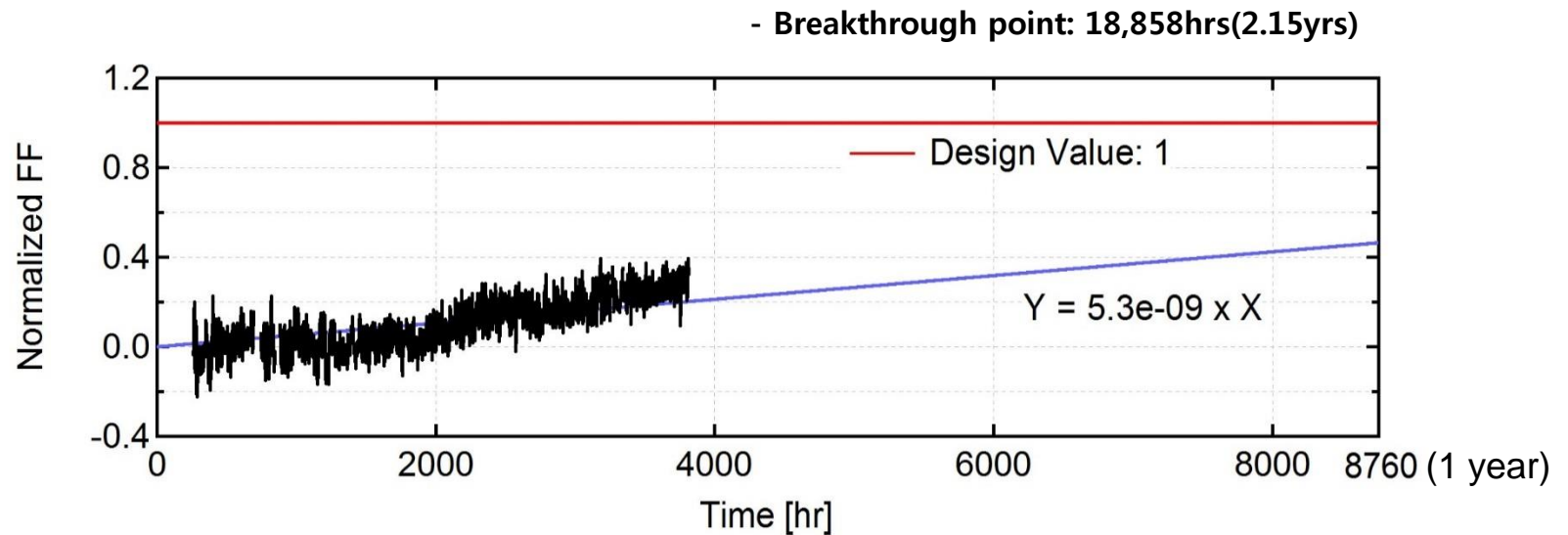
\*\*FF, Fouling factor



# FOULING FACTOR ANALYSIS: HTC\* & FF\*\* PROFILE

FF value is expected to be less than the design value after 1 year

- Expected Trend of Overall Fouling Factor Increase



# VISUAL INSPECTION RESULT



# VISUAL INSPECTION RESULT

After 5-month test, very thin film layer was entirely formed on the tube, which expected to be soft scale

- Before 5-month Scale Test



- After 5-month Scale Test



# VISUAL INSPECTION RESULT

Very thin film layer was easily removed after water flushing and scale composition was confirmed as mostly  $\text{CaCO}_3$  (Soft Scale) by chemical analysis

• Before 5-month Scale Test



• After 5-month Scale Test



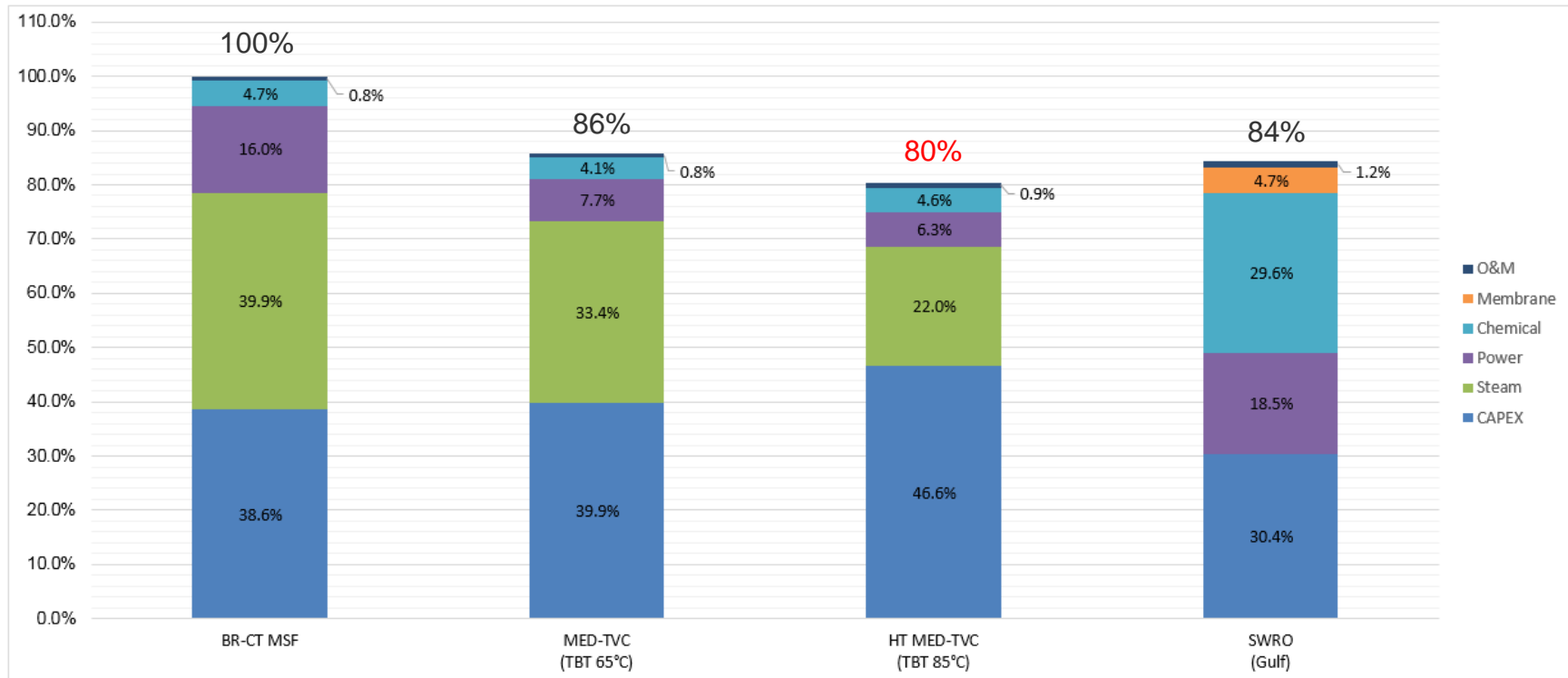
• Cleaning with water



- Chemical composition analysis
  - $\text{CaCO}_3$  is a dominant part of scale.

# TECHNO-ECONOMIC ANALYSIS

- Comparing to conventional MED-TVC (PR 11.5), High TBT MED-TVC plant (PR 18.3) has significant improvement in HTC and reduction in OPEX
  - Steam consumption reduction: Over 30%
  - LCOW\* reduction: 6.4 %



\*LCOW, Levelized cost of Water

- Based on Fuel Cost of 24 USD/bbl

# CONCLUDING REMARKS

- Based on technical and experimental studies (2008~2012), high TBT (85°C) MED-TVC is a competitive technology.
  - ✓ PR is increased from 9-11 to **13.5-15.8 kg distillate/2,326kJ**
  - ✓ **33% Less Steam Consumption**
- SWCC-Doosan Joint Demonstration (5 months) verified the High TBT (85°C) MED-TVC technology under Jubail seawater condition (2016~2017).
  - ✓ HTC & FF monitoring: **Consistent HTC and FF trend show high TBT (85°C) MED-TVC operation can be achieved.**
  - ✓ Visual inspection: **Only thin film soft scale appeared on the tube surface, which can be easily removed by water flushing**
  - ✓ Chemical analysis: Ongoing to verify scale composition
- Based on demonstration test, it is proved that HT MED-TVC is technologically viable in Gulf Area.



**DTRI**

معهد الأبحاث و تقنيات التحلية  
Desalination Technologies Research Institute



# ***Building Your Tomorrow Today***

