معهد الأبحاث و تقنيات التحلية
Desalination Technologies Research Institute

Crevice Corrosion within RO desalination plants

– Case studies & Recommendations –

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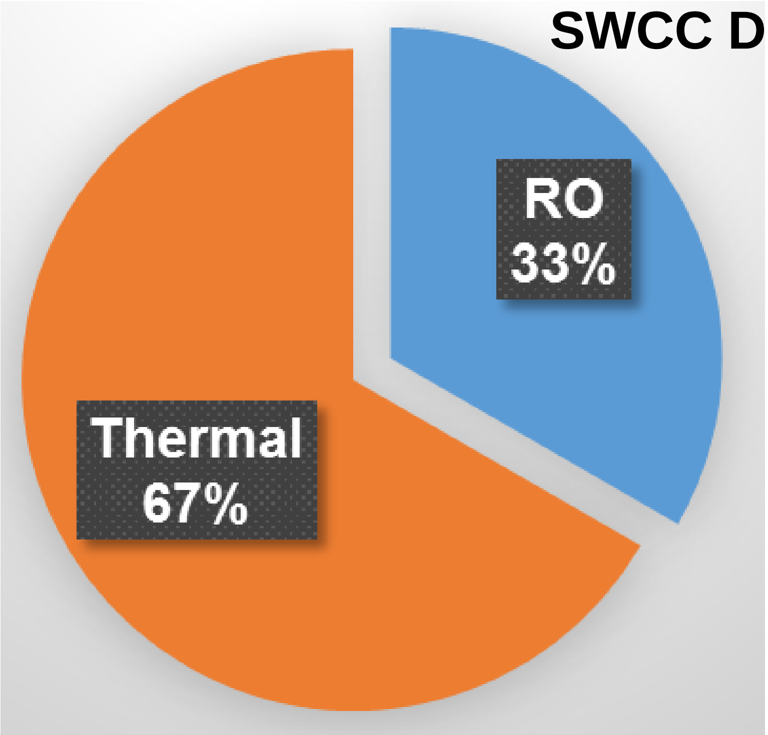
المؤسسة العامة لتحلية المياه المالحة
Saline Water Conversion Corporation

Agenda

- RO plants within SWCC
- Materials selection for RO plants
- Crevice Corrosion record within SWCC RO plants
- Crevice corrosion research findings
- Case studies
- Recommendations

RO plants within SWCC

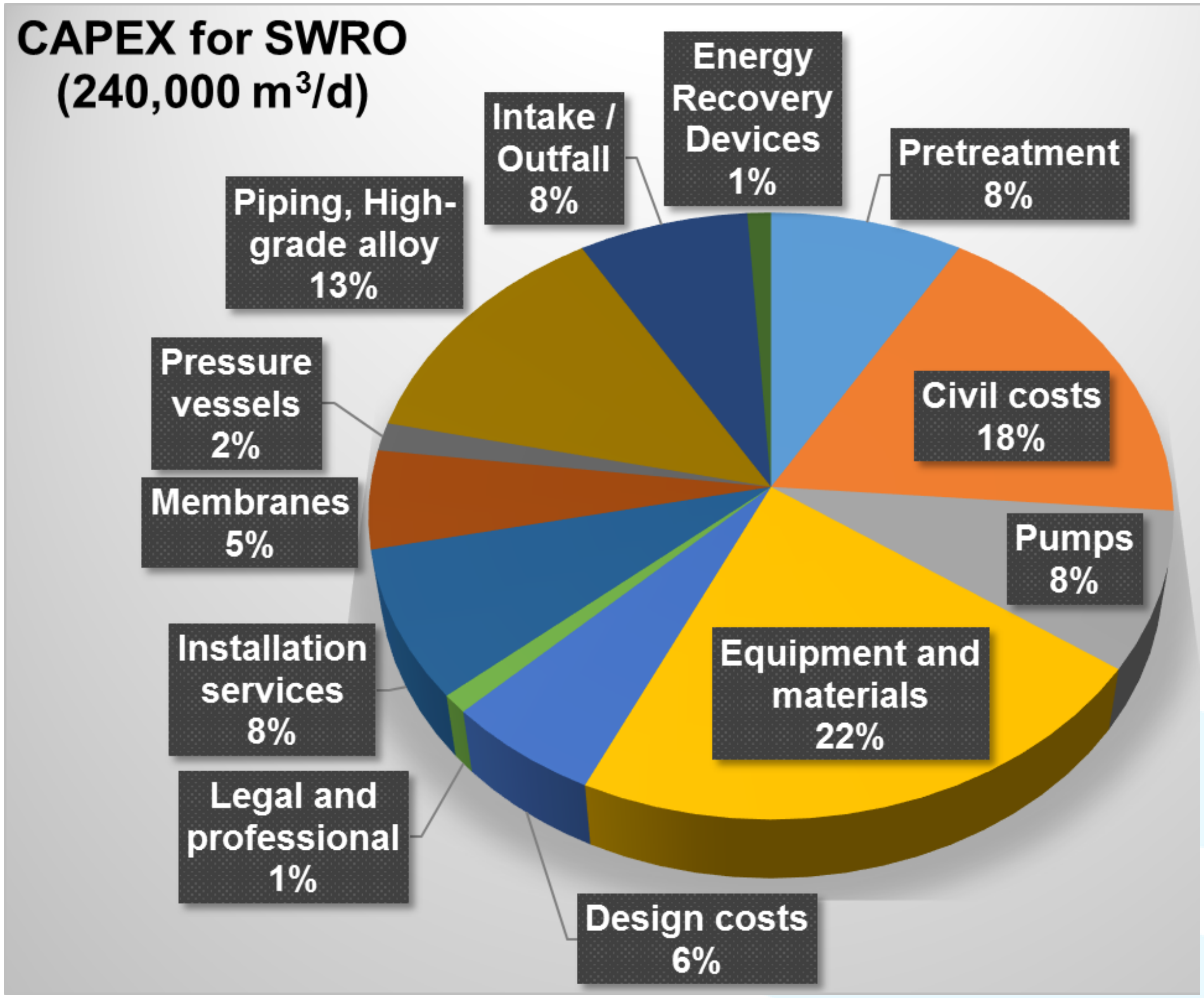
SWCC Desalination processes distribution



SWRO		
Plant	Design Production	
	m^3/day	Operation Year
A	56,800	1989
B	56,800	1994
C	240,000	2012
D	90,910	2000
E	128,180	1999
F	4400	1990
G	4400	1989
H	4400	1986

Materials selection for RO plants

Pipe & High Grade Alloys
+
Energy Recovery Device
+
Pumps
=
22%



Materials selection for RO plants

- ✓ Materials selection for RO plants has been studied by many authors (Olsson, 1983-Oldfield, 1985, Ata Hassan, 1989, Oldfield,1991, Oldfield,1997,…… Larché, 2013)
- ✓ The key factor in using SS and/or nickel base-alloys in RO plants is to choose the grade the more resistant to crevice corrosion
- ✓ After replacement of the failed 316L by the excellent 254SMO, there has been a trend during the 1990s to look for less costly alternatives such as the duplex grade 2205 and the austenitic 904L. Then by super-duplex recently

Equipment	*Recommended materials*
High Pressure:	
Piping	AL-6XN, SAF 2507, 254 SMO, Zeron 100
Valves	AL-6XN, SAF 2507, 254 SMO, Zeron 100
Fittings	AL-6XN, SAF 2507, 254 SMO, Zeron 100
Pump Bodies-RO High Pressure Booster Pumps, ERD Pressure Booster Pumps	AL-6XN, SAF 2507, 254 SMO, Zeron 100
RO Membrane Modules	FRP
Energy Recovery Devices (Seawater and Concentrate)	FRP3, AL-6XN, SAF 2507, 254 SMO, Zeron 100

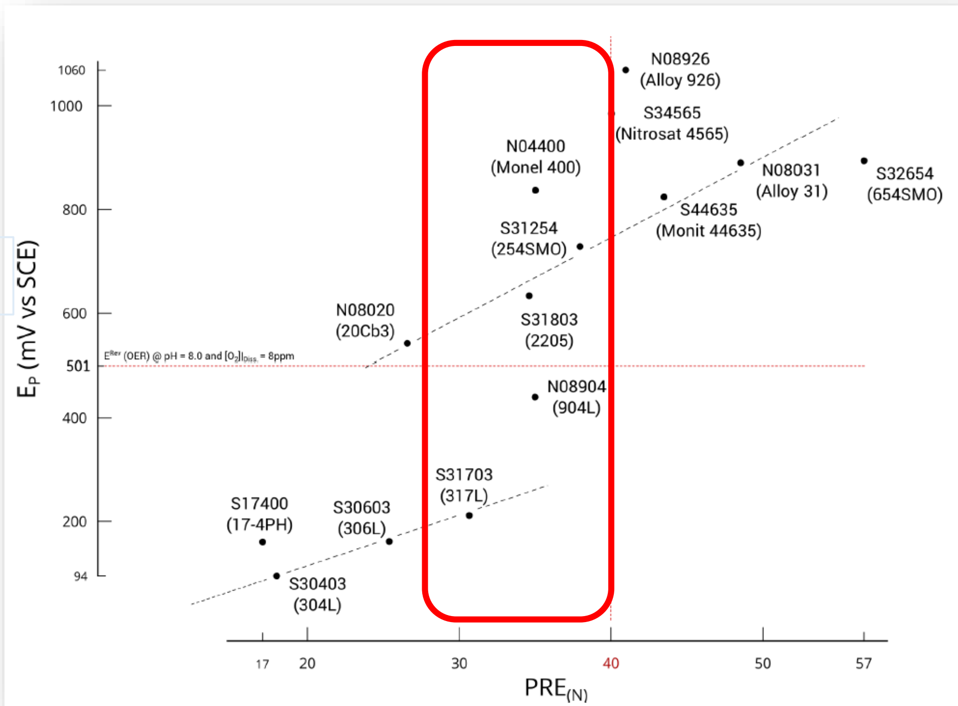
Grade developed by Rolled Alloys (Superduplex with high W content)

Materials selection for RO plants is subject to continuous up-date based on crevice corrosion studies findings, **RO plants experience** and SS development.

Materials selection for RO plants

SWRO materials specification in many plants is following standards such as ISO 21457 & NORSOK M-001:
Any material exposed to oxygenated seawater shall be made of seawater resistant alloy based on its **PREN which has to exceed 40**

E_p: Breakdown potential



❖ The PREN limit (≥ 40) has been derived from end-user experience (mostly in the North Sea) and a number of long-term exposure test programs.

Materials selection for RO plants

- ✓ A materials selection strategy based on PREN alone is restrictive and can be over-conservative. …..*Rincon-Ortiz, 2014*

- ✓ No clear correlation between E_{RP}- E_{OC} and PREN was found for higher alloys such as 254SMO, duplex and nickel alloys, suggesting PRE(N) is an inadequate materials selection criterion…..*Rincon-Ortiz, 2014*

- ✓ The most important criteria of any accelerated laboratory test for localized corrosion is that it must rate alloys consistent with service performance case histories in environments that cause localized corrosion…….*Manning, 1983*

Crevice Corrosion record within SWCC RO plants

Materials used within SWCC RO plants

Plant	HP pump			HP pipe	Valve		Energy Recovery Device (ERD)		
	Impeller	Casing	Shaft		Inlet HP pump	Feed control	Impeller	Casing	Shaft
A	Alloy-20	316	Alloy-20	317L	Cast-Fe (C) -316L (D)	316L	Alloy 20	316	Alloy 20
B	317	317	317	254 SMO	Cast-Fe	Duplex CD4MCu	NA	NA	NA
C	317	317	317	254 SMO					
D	Alloy-20	317	Alloy-20	317L → 254SMO	Cast-Fe	316	Hastelloy	316L	Alloy-20
E	Duplex CD4MCuN	Duplex	2205	254 SMO	C-Steel	Duplex	2507		
F	317	317	Nitronic® 50	254 SMO	Cast-Fe(B)	317L	317	317	Nitronic® 50

Alloy	Cr	Ni	Mo	Mn	Cu	W	N	PREN
316L	16.7	10.7	2.05	1.5	---	---	---	23.5
317L	18.2	13.7	3.1	2	---	---	---	33.2
Nitronic® 50	23	13.5	3	6	---	---	0.4	39.3
Duplex CD4MCuN	25	6	1.7	1	2.8	---	0.15	32.2
2750	24.8	6.5	3.7	0.8	0.08	1.99	0.2	40.2
254SMO	19.9	18	6.1	0.7	0.68	0.05	0.2	43.2
Alloy 20	19	33	3	2	4	---	---	23.5

Crevice Corrosion record within SWCC RO plants

Number of Crevice corrosion Occurrence

Plant/ commissioning year	HP pump			HP pipe	Valve	Energy Recovery Device (ERD)		
	HP pump Impeller	HP pump Casing	Shaft		Feed control	ERD Impeller	ERD Casing	ERD Shaft
A/1990	0	3	0	8	6	0	3	0
B/1989	2	2	2	2	2	2	2	2
C/1986	0	0	0	0	4	0	0	0
D/1989	0	0	0	0	0	0	0	0
E/2012	0	0	0	0	0	0	0	0
F/1999	0	0	0	0	0	0	0	0

2015 Survey

SWCC experience with crevice corrosion need rational & more strict Re-evaluation

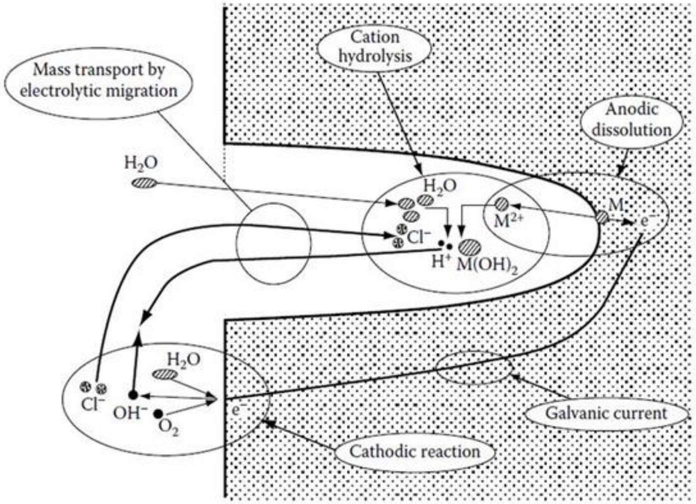
Crevice corrosion within RO research findings

I. Initiation Stage:

1. De-oxygenation of the small **amount of solution within the crevice .**
2. Build-up of **chloride ions and acidity within the crevice** resulting from migration effects and hydrolysis reactions respectively.
3. **Breakdown of** the alloy's protective **passive film within the crevice**.

II. Propagation stage:

4 . Propagation of the corrosion process .



The propagation process is essentially controlled by the level of oxidizing species available for the cathodic reaction in the overall corrosion process.

Previous studies findings: cathode area (outside crevice gap) would be microfouled with biofilm formation affecting both the mixed potential and the cathodic process kinetic

Crevice corrosion within RO research findings

Borderline attitude

NORSOK standard M-001 Rev. 4, August 2004

Alloy 625 and stainless steels with PRE ≥ 40 are borderline cases and should not be used for mechanical connections without cathodic protection when their material temperature exceeds ambient North Sea sea water temperatures. Threaded connections are particularly susceptible to crevice corrosion.

SS grades with PREN above 40 are also susceptible to crevice corrosion in seawater depending on:

1. Crevice geometry.
2. Service conditions (e. g. temperature, chlorination, oxygen content),
3. Grade Metallurgy (e. g. cast or wrought alloys)

Crevice corrosion within RO research findings

1. Crevice geometry.

DTRI works, 1995

Multiple crevice former: better crevice corrosion resistance performance in the natural gulf seawater for S32750 compared to S31254.

Flat crevice former: better crevice corrosion resistance of S31254 compared S32750

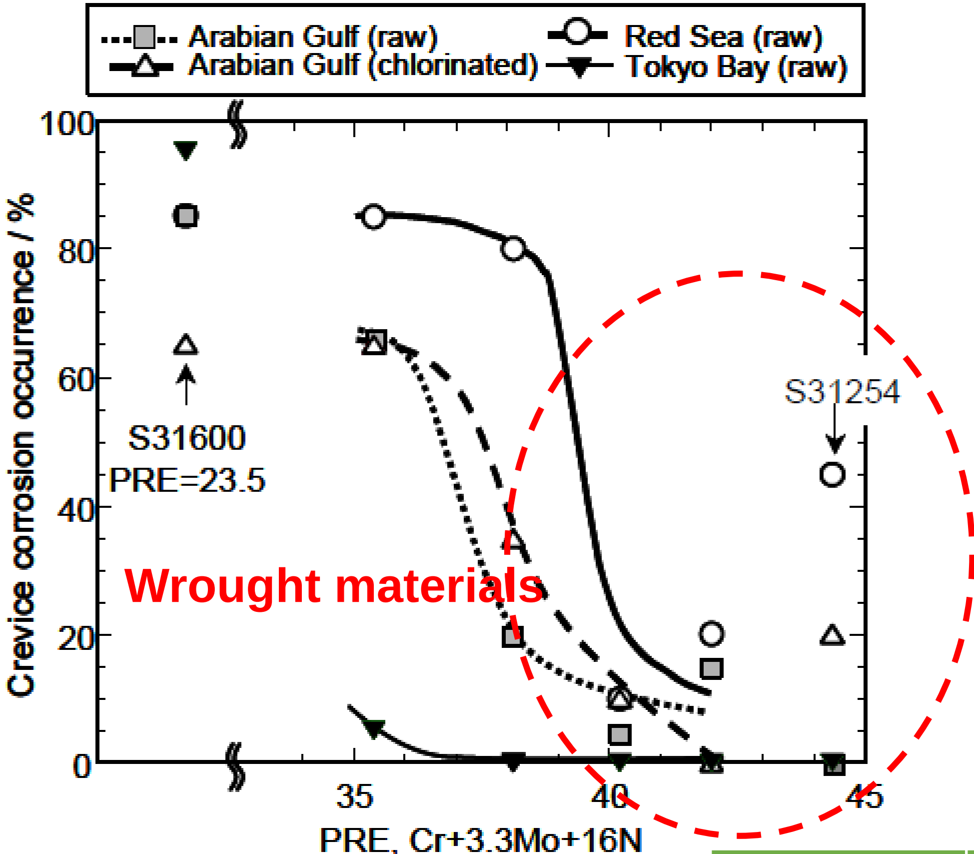
DTRI/FCI, 2015

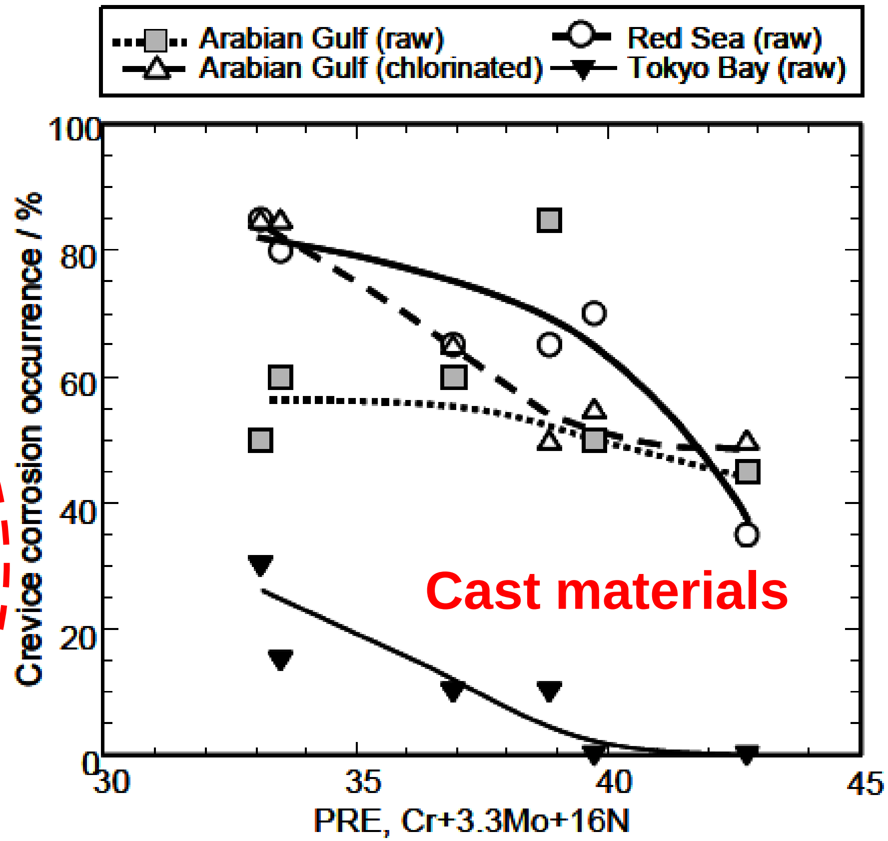
	S32205		S32750		S31254		S31266		N06625	
Gulf Seawater (18-36 °C)	1/5	4/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5
Gasket Pressure (N/mm^2)	3	20	3	20	3	20	3	20	3	20

Crevice corrosion within RO research findings

DTRI/Ebara Works, 2007

Grade Metallurgy & service conditions





	Gulf Seawater	Red Sea	Tokyo Bay
TDS (ppm)	45,000	41,000	38,000
[Cl$^-$] (ppm)	23,000	22.219	18,000

Crevice corrosion within RO research findings

DTRI/FCI, 2015

2. Service conditions (e. g. temperature)

	S32205		S32750		S31254		S31266		N06625	
Gulf Seawater (18-36 °C)	1/5	4/5	0/5	0/5	0/5	0/5	0/5	0/5	0/5	1/5
Brest Seawater (30 °C)	0/5	4/4	0/5	0/5	0/5	**1/5**	0/5	0/5	0/5	3/5
Gasket Pressure (N/mm^2)	3	20	3	20	3	20	3	20	3	20

Similar performance of superduplex 2750 in the two seawaters contrary to 254SMO

Parameter / Location	TDS (ppm)	pH	[Cl-] (ppm)	O_2diss (ppm)	Conductivity (µS/cm)
Brest	35,000	8.1±0.1	19,373	6	54,000
Jubail	43,800	8.1±0.1	24,090	7	62,800

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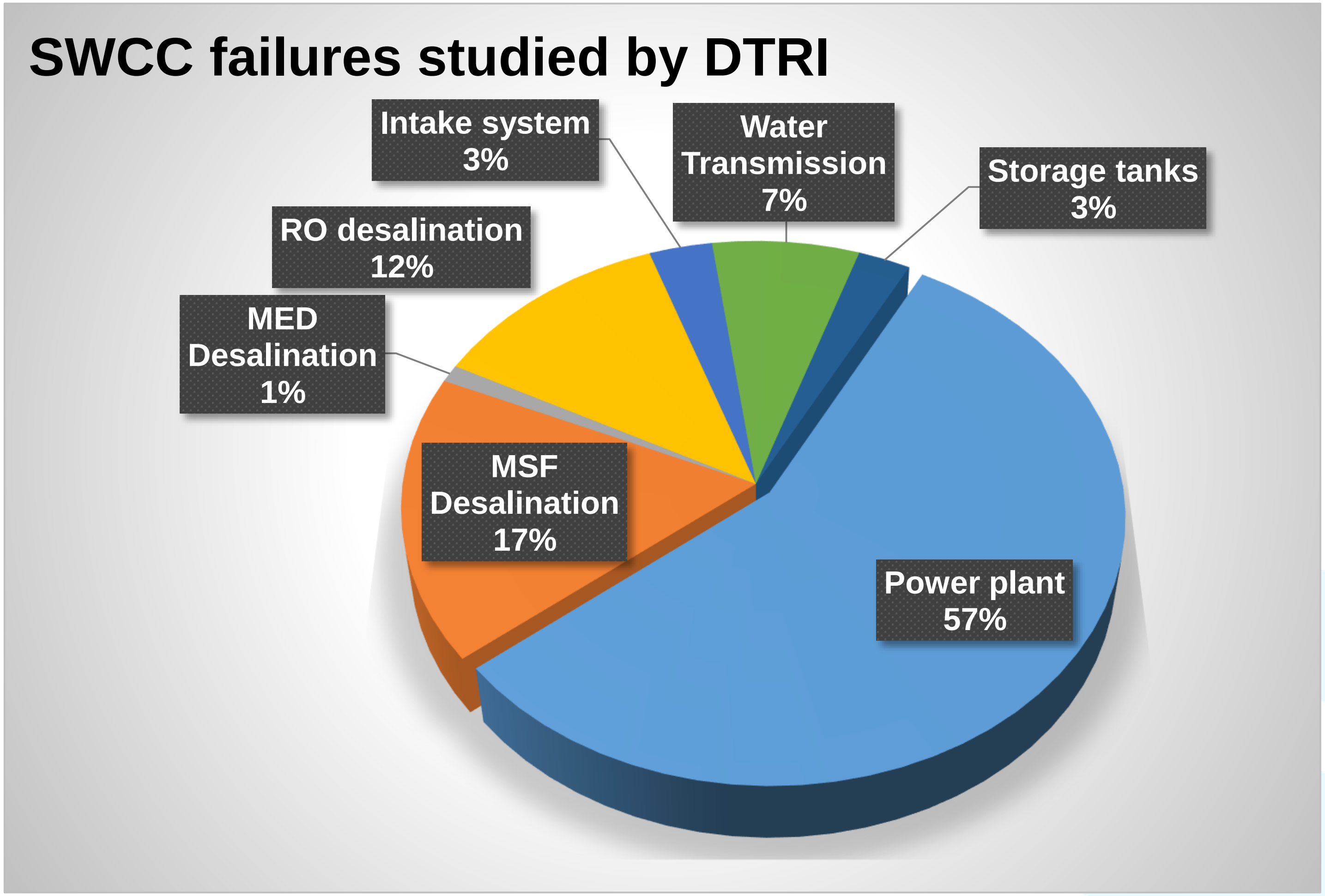
Case studies



Case studies

Year: 2002
Part: Micro-cartridge filter
Component: Bottom face of top flange basket
Material: 904L
Environment: Pre-treated aerated seawater
Service years: 2 years

Case studies

Year: 2009
Part: Nozzles connectors
Component: Bending inlet pipe
Material: 254SMO
Environment: Pre-treated aerated seawater
Service years: 11 years

Case studies

Year: 2016

Part: Nozzles connectors

Component: Bending inlet pipe

Material: 317L

Environment: Pre-treated aerated seawater

Service years: 11 years

Recommendations

- Crevice corrosion risk within RO plants need a strict assessment (consortium program could be advised including private desalination sector).
- Crevice corrosion Factors such as crevice geometry, material metallurgy need to be defined within SWCC plant.
- While 317L is largely used in SWCC old plants, its performance against crevice corrosion should define the need for a replacement by highly resistant alloy or the combination with well designed cathodic protection.
- Victaulic joints represent a location for crevice corrosion risk.
- Borderline attitude of high PREN alloys (2750 & 254SMO) should be verified through RO plants experience.
- The unification of crevice corrosion testing conditions (metallurgy, crevice geometry, seawater characteristics, test duration, type of crevice former, Anode/Cathode ratio, Surface finishing) should be followed for easy comparison between findings.

Thank you For your Attention