MULTI Alloys

A division of EMVAfrica

GUIDE TO STAINLESS STEELS AND DESALINATION

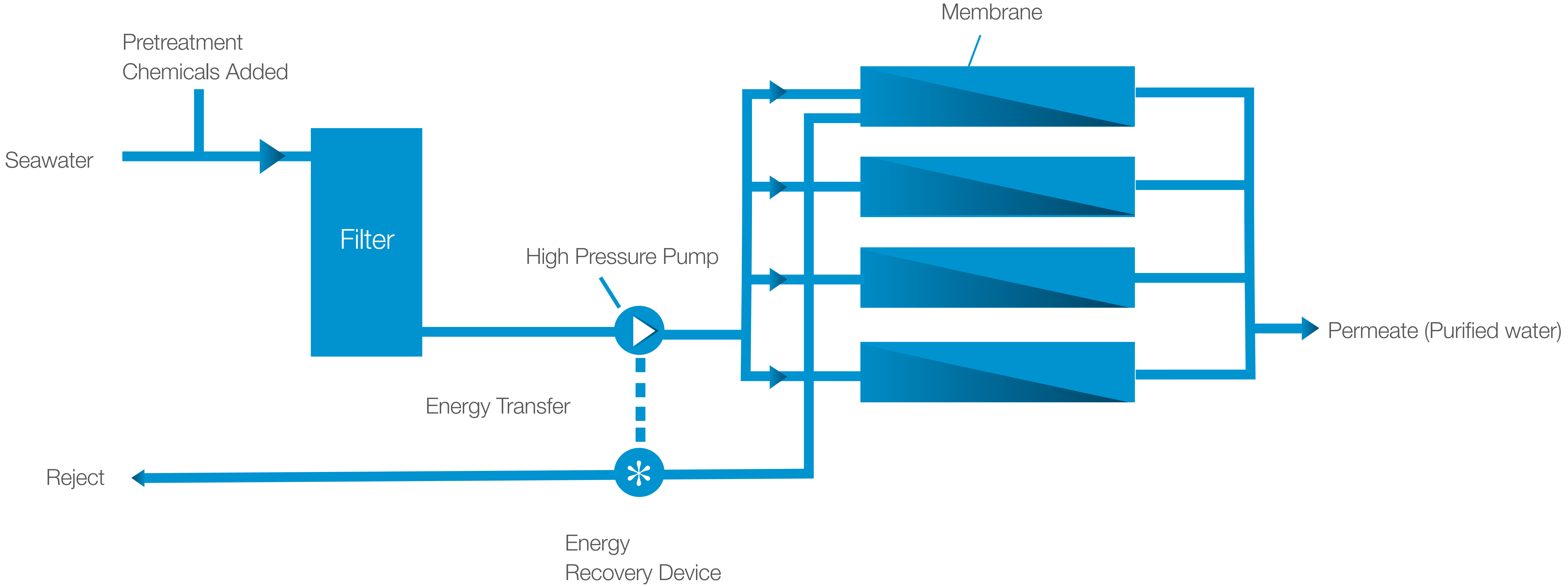
ADDING VALUE THROUGH EXPERIENCE

1.0 DESALINATION: AN OVERVIEW.

Water, water everywhere, nor any drop to drink.

71% of the Earth's surface is covered by water but of this 96.5% is found in seas and oceans. Population growth, urbanisation and industrialisation have directly or indirectly brought about the situation that a water crisis exists or one is looming. For many access to safe water has improved but this has exacerbated the shortage to the point that future geo-political developments may target ownership of this limited resource. The solutions are varied but desalination of seawater or brackish water is one of them.

In the southern African context the very low rainfall in the Cape has raised the profile of the use of desalination as one means to relieve the shortage of safe water but in fact the trend started in 2010 with a number of small regional plants. Although not seawater fed, there have also been a number of plants set up to treat polluted water resulting from mining and industrial activity. The processes used may be classified according to the technology used - membrane (reverse osmosis and nanofiltration) or thermal (distillation, evaporation and crystallisation). Each has their pro's and con's but membrane technology has been favoured in South Africa for seawater desalination and sea water reverse osmosis SWRO is the focus of this review.



Typical simplified SWRO process flow diagram.

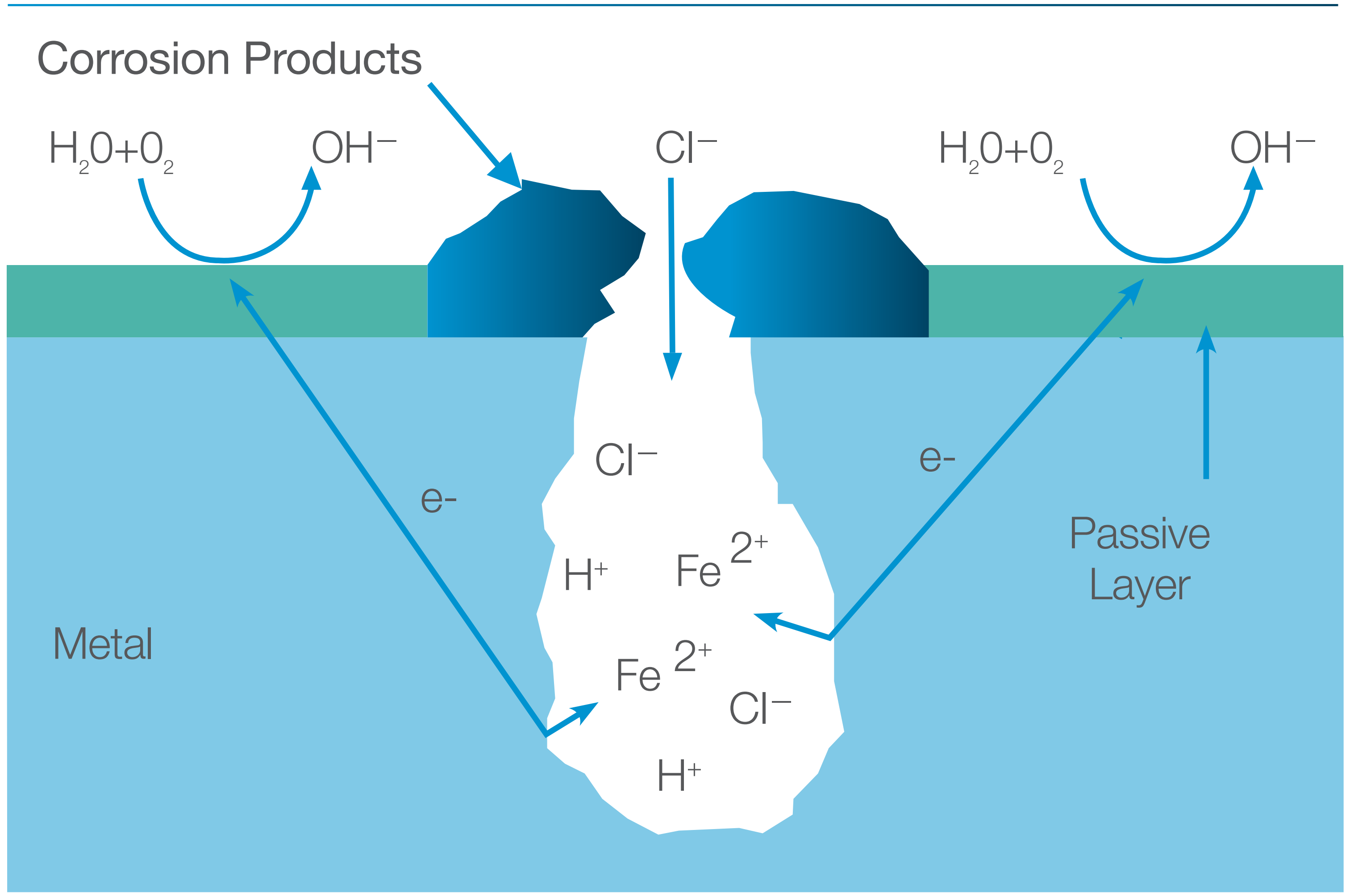
2.0 DESALINATION: CORROSION CONSIDERATIONS.

The chloride content of seawater will accelerate general corrosion but it is 3 forms of localised corrosion that receive much of the attention - pitting and crevice corrosion and stress corrosion cracking.

Galvanic corrosion, erosion corrosion and Microbiologically induced corrosion are other damage mechanisms that may be encountered in seawater applications.

2.1 PITTING CORROSION

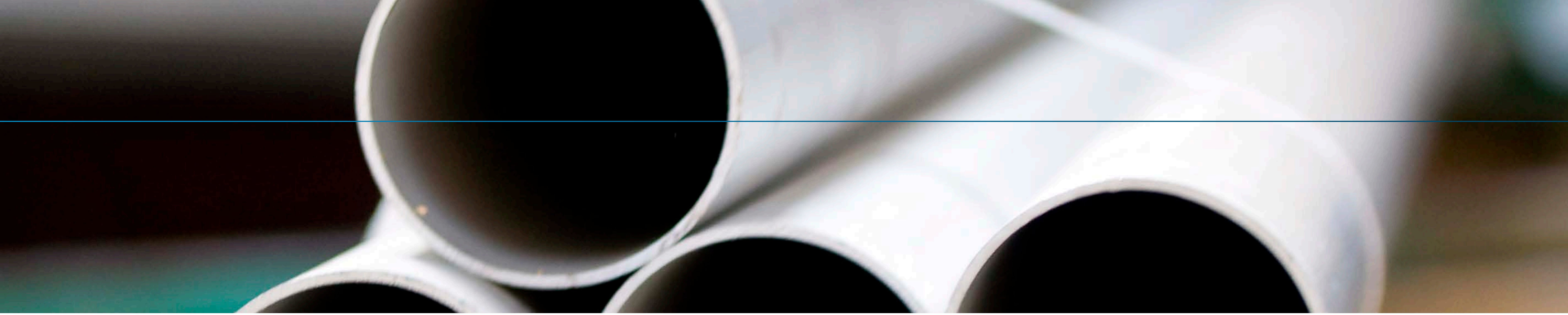
Pitting corrosion refers to a localised break down of a normally passive film and it occurs in stainless steels in neutral or acidic chloride solutions. Other parameters which may influence the process are temperature, oxygen level and in the case of chemical solutions, the red-ox potential of the solution. There are several laboratory tests available to rank the resistance of stainless steel grades to pitting corrosion and the results are reported as the critical pitting temperature (CPT) – the lowest temperature at which pitting takes place. Years ago a useful measure based on composition was established and this is known as the pitting resistance equivalent (- PRE) (see Table 1)



$$M^+ + Cl^- + H_2O \rightarrow MOH\downarrow + \underline{H}^+ + Cl^-$$

2.2 CREVICE CORROSION

Crevice corrosion takes place under the same conditions as pitting corrosion but it is initiated more readily in a crevice as may exist in unsealed flange joints and threaded connections. Critical crevice corrosion temperature is a measure used rank the resistance of stainless steel grades and this form of attack. Crevice corrosion may avoid by appropriate design and construction.

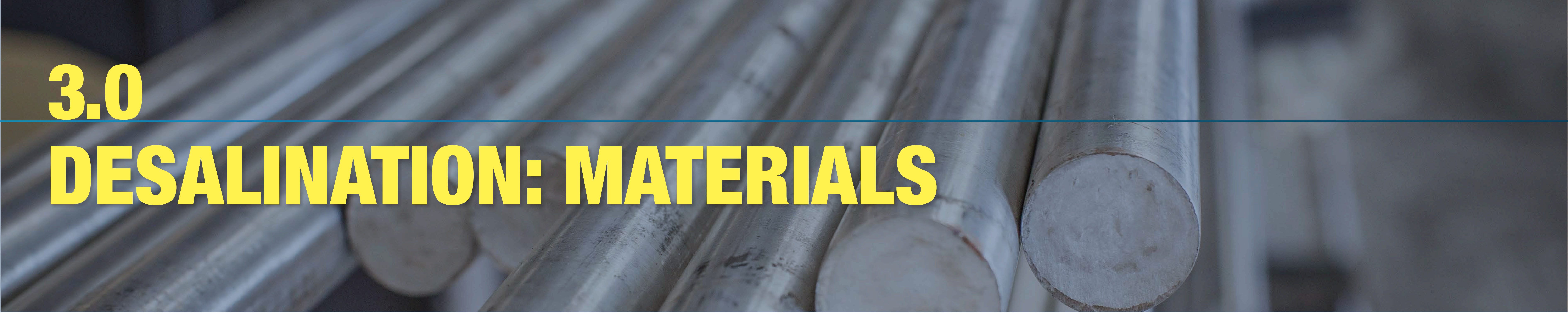


2.3 STRESS CORROSION CRACKING

Stress corrosion cracking (SCC) refers to a damage mechanism that involves the simultaneous presence of a tensile stress, a corrosive environment and a susceptible metal / microstructure. Whilst SCC may occur in several combinations of metals and specific environments, for stainless steels it is a range austenitic grades in the presence of chlorides that are at risk. Process parameters that may influence the occurrence of SCC are:

- Temperature
- pH
- the stress level (may be applied or residual)
- the level of chlorides.

In desalination applications chlorides levels will differ between the feed (seawater) and the rejects which are effectively a concentrate that remains after the "purified" water has been separated.



3.0 DESALINATION: MATERIALS

While copper and copper alloys have a long history of successful service in seawater, its stainless steels that are used extensively in SWRO plants. The accompanying tables lists some grades that may have been used in desalination plants for one or other purpose. The list includes both duplex and austenitic grades the former being LDX 2101, Alloy 2205 and SAF 2507. The empirical parameter, PRE, is also listed and is measure of the resistance the alloy will display to pitting corrosion.

TABLE 1: Typical Chemical Compositions and Indicative PRE-numbers of some Stainless Steels

Grade	EN	UNS	%Cr	%Ni	%Mo	%N	PRE (1)
316L	1.4404	S31603	17	11	2.1	0.06	25
LDX2101	1.4162	S32101	21	1.5	0.3	0.22	25
904L	1.4539	N08904	20	25	4.5	0.06	36
2205	1.4462	S32205	22	5.5	3.1	0.17	35
254SMO	1.4547	S31254	20	18	6.1	0.2	43
SAF2507	1.4410	S32750	25	7	4	0.27	43

(1) PRE = %Cr+3.3%Mo+16%N

Table 2 lists some mechanical properties of these alloys and the high strengths of the duplex grades is evident.

A primary feature of the duplex stainless steels is their very good resistance to stress corrosion cracking. There are a number of laboratory test methods for measuring resistance to SCC and these may be carried out with samples immersed or under simulated evaporative conditions. Table 3 is a ranking of several austenitic and duplex alloys using the drop evaporation test. The test simulates severe conditions which may not arise in SWRO applications but it does, nonetheless illustrate that 316L is more prone to SCC than the higher nickel austentic grades and the duplex stainless steels.

TABLE 2: Typical Mechanical Properties of some Stainless Steels

Grade	$R_{po.2}$	R_m MPa	A_5 %	Design Stress (MPa) at 100˚C	200˚C
316L	220	520	45	143	130
LDX2101	450	650	30		
904L	220	520	35	157	137
2205	460	640	25	240	210
254SMO	300	650	40	205	187
SAF2507	530	730	20	300	267

TABLE 3: Stress Corrosion Cracking Susceptibility Indicator (2)

Grade	Design Stress At 200˚C MPa	Threshold Stress % of Design Stress	Threshold Stress MPa
316L	130	10	13
904L	137	60	82.2
2205	210	30	63
254SMO	187	80	149.6
SAF2507	267	60	160.2

(2) Based the Drop Evaporation Test using 3500ppm chloride at 200 deg C and using Design Stress at this temperature

4.0 CONCLUSIONS AND DISCUSSION

Desalination is but one approach to addressing water shortages in parts of the world. There is much attention being given to reducing energy costs that are inherent in the different processes and this in turn has focussed on energy recovery, the use of solar or wind power and off-peak energy use.

The strength benefit of duplex stainless steels is well established and in respect of SWRO their use may may permit the reduction of wall thickness of pipe etc without sacrificing the allowable operating pressure when compared with 316L. In addition, although 316L may have adequate resistance to the product water and atmospheric corrosion in hot and humid climates, it is not suitable for seawater containing oxygen even at a ppm level. It was used extensively in old SWRO plants with poor results.

Alloy 2205 is being used increasingly for these applications as it does offer good resistance to stress corrosion cracking and because of its higher strength. However field experience has been that in air saturated sea water it may still display inadequate pitting and crevice corrosion resistance.
For long term, reliable performance the use of 254SMO of Super Duplex 2507 is indicated and this is born out in practice.

Further considerations when using duplex or super duplex materials is the use of a suite of additional tests as quality assurance aids to ensure the desired corrosion resistance is attained. Some of these tests are ASTM E562 (Phase Distribution), ASTM A923 (Intermetallic Phases) and ASTM G48 (Pitting and Crevice Corrosion resistance). It should be noted that in duplex stainless steels the austenite and ferrite phases will have different compositions and so too the elements comprising the PRE measure will be partitioned differently in the 2 phases. This being the case it may be possible for the 2 phases to have differing PRE measures. In the interest of end user certainty some manufacturers may commit that the PRE for the 2 phases will be equal (+/- 1).

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