II SEMINARIO INTERNACIONAL DE DESALACIÓN EN ANTOFAGASTA

Use of duplex, super duplex and hyper duplex stainless steel grades for environments with high content of chloride

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Introduction

- Fresh water insuficiency
  - 97% Salt water: Oceans
  - 3% Fresh water: lakes, rivers, ground and ice
- Desalination alternative
- Corrosive environment
  - Seawater: 35g of salt per 1kg water
- New materials demand
  - Superaustenitics and Duplex Stainles Steels

Desalination Process

- Removal of salt and minerals up to potable or industrial levels
- Methods:
  - Evaporation
  - Destillation
  - Membrane Systems
- Reverse Osmosis
  - High pressure system (50-80atm, 730-1170 psi)
  - Tube and pipe lines with salty water

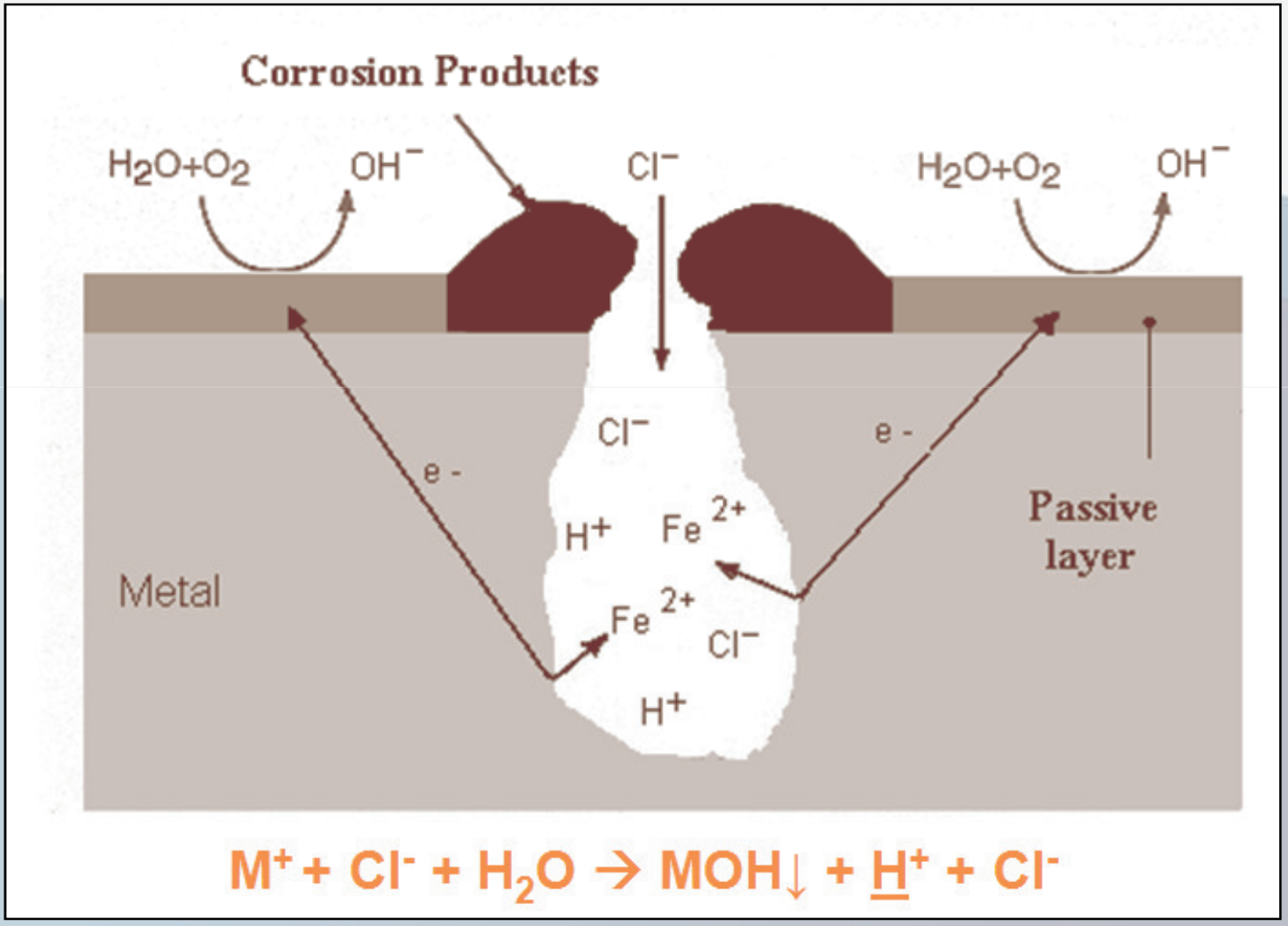
Corrosion

- Chloride containing environments
  - Pitting Corrosion
  - Crevice Corrosion
  - Stress Corrosion Cracking

Pitting Corrosion

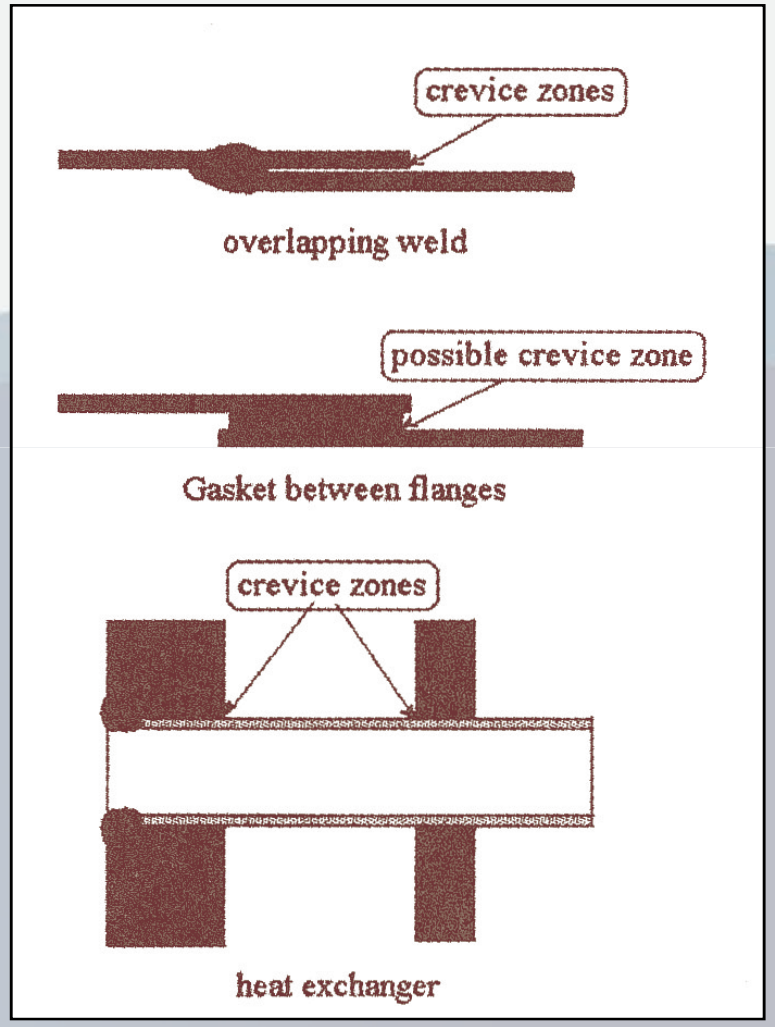
- Localized corrosion mechanism, very common
- Affected by
  - Chloride concentration
  - Potential, oxidizing or reducing environment
  - Oxygen supply
  - pH
- Alloying with Cr, Mo & N improves pitting resistance

Pitting Corrosion

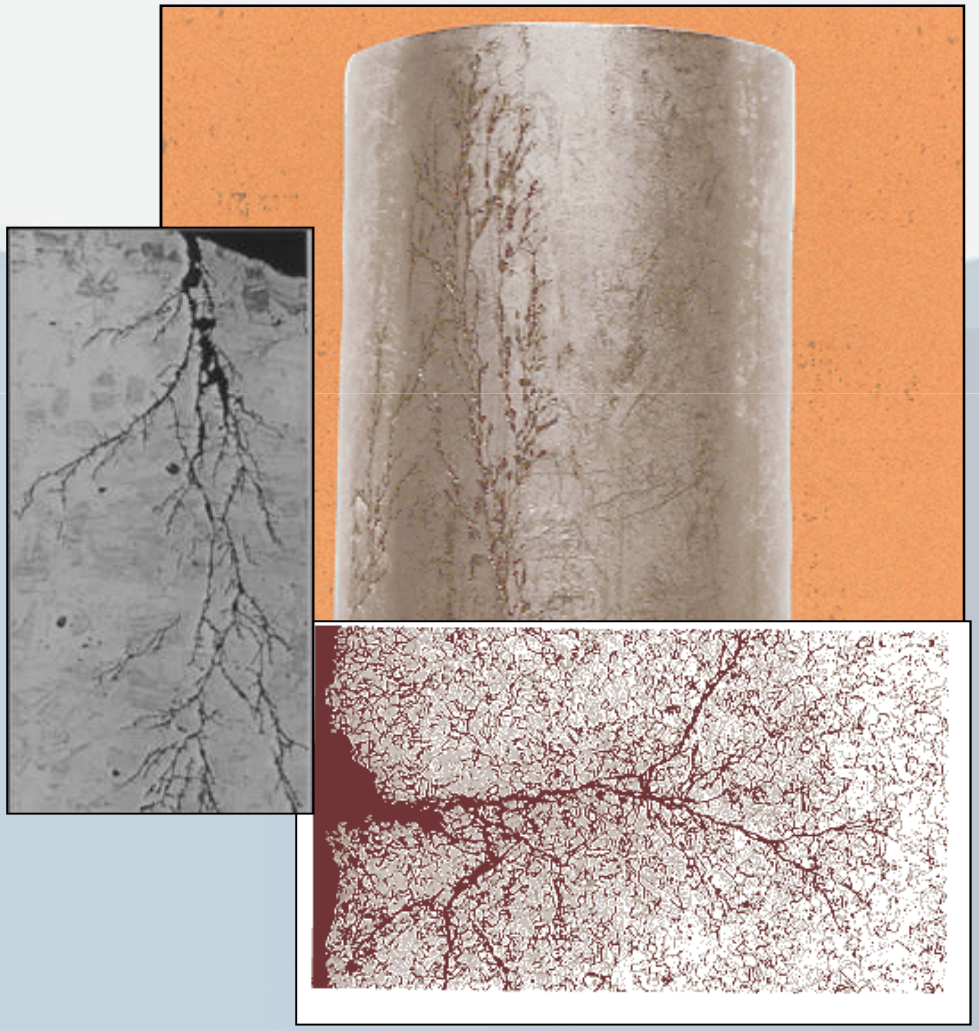


Crevice Corrosion

- Same mechanism as pitting corrosion
- Crevice corrosion is also affected by:
  - Geometry of crevice
  - Material of crevice former
  - Anode/cathode area ratio
  - Deposits on metal surface
- Crevice corrosion can often be avoided by changing the construction!

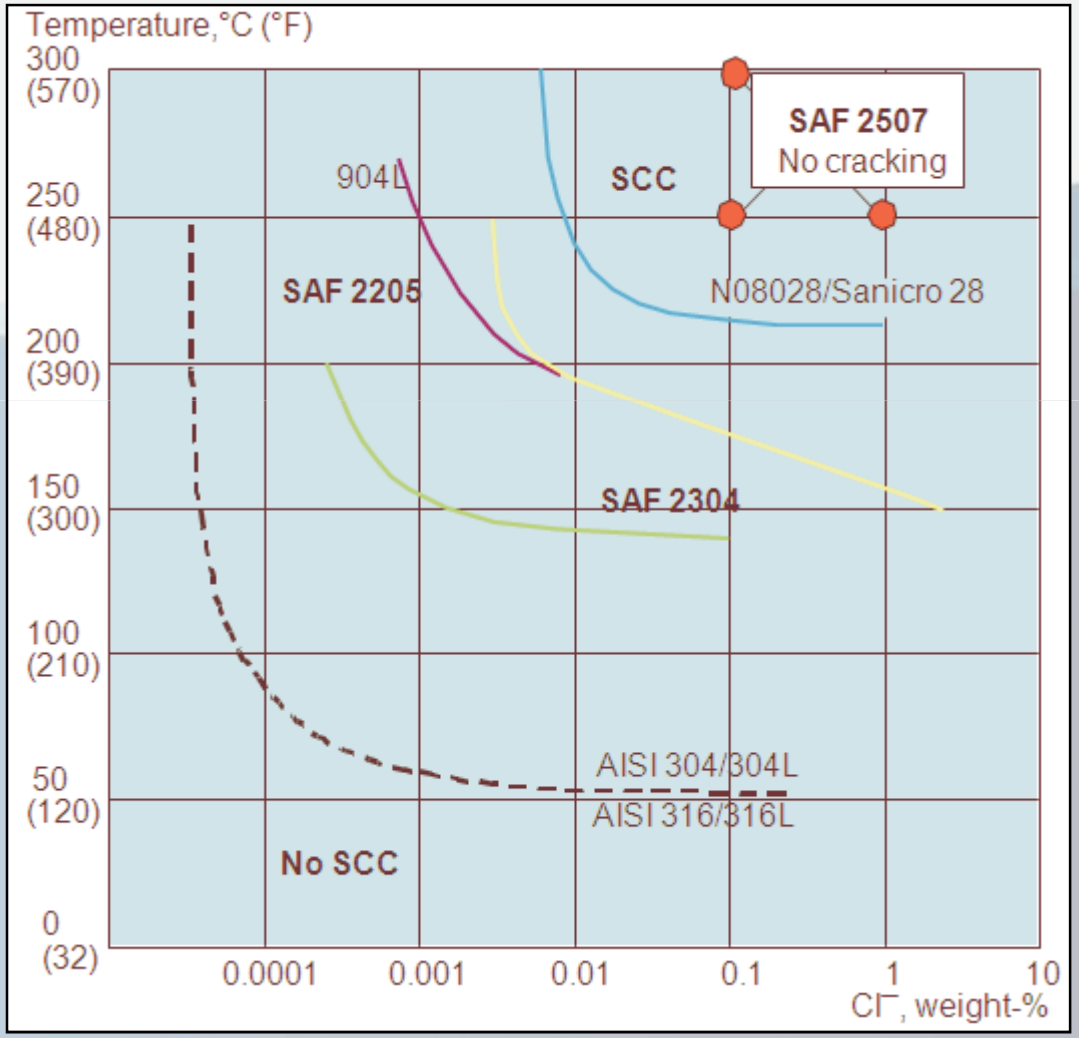


Stress Corrosion Cracking



- Austenitic´s weakness
- Temp > 60 °C
- Applied traction/axial stresses or residual stresses
- Corrosive Media: Cl^-, H_2S (Sulphide SCC), OH^-
- Short time period until failure!

Stress Corrosion Cracking



Pitting Resistance Equivalent

- PRE Number: used to compare the pitting corrosion resistance of materials
- How to calculate?

$$PRE = \%Cr + 3{,}3 * \%Mo + 16 * \%N$$

**This is the general formula. Can be found with addition of other elements*

- Why Cr, Mo and N?
  - Improve pitting corrosion resistance
- How to use?
  - The higher, the better!

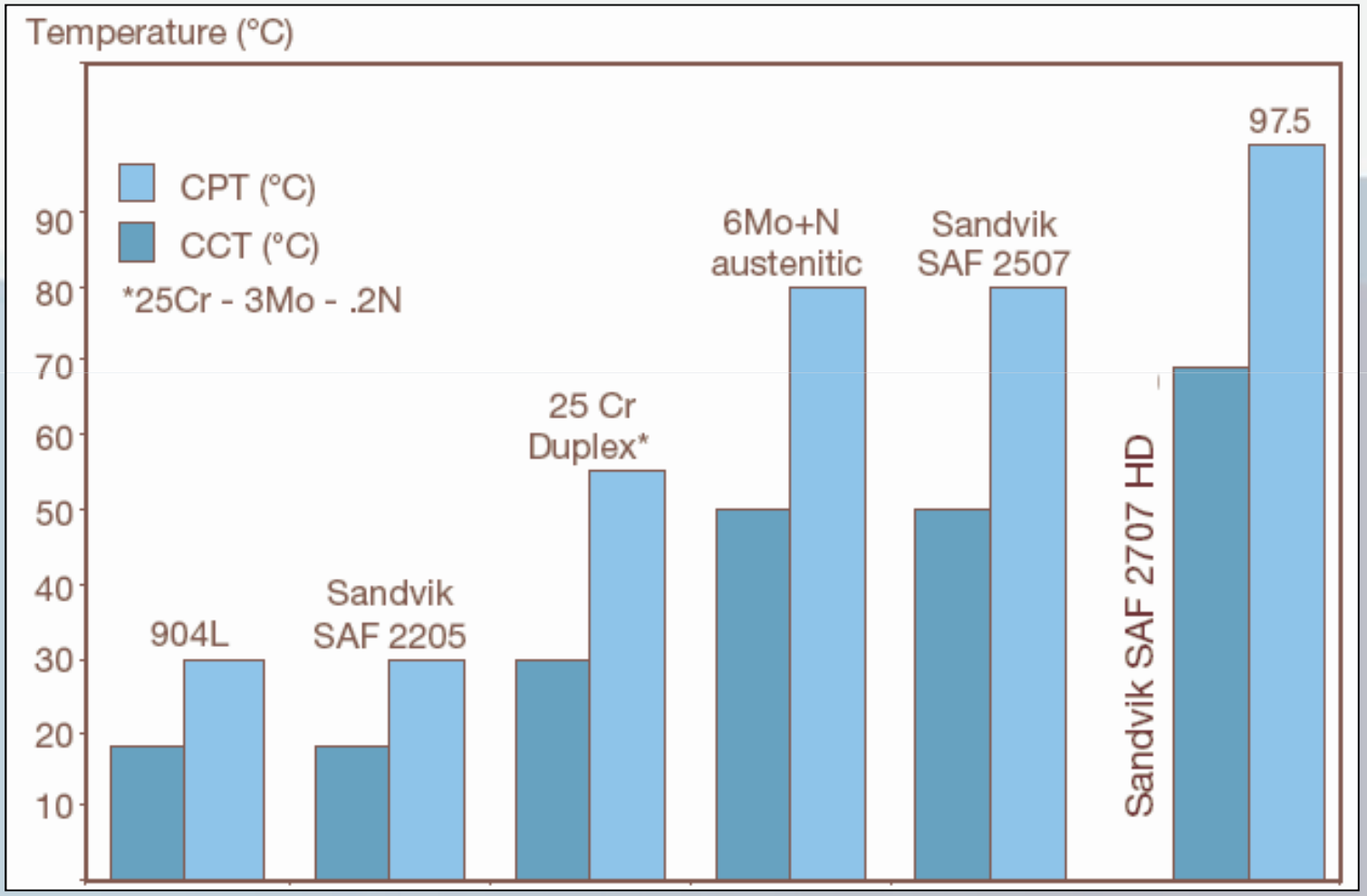
PRE Number

PRE = %Cr + 3,3%Mo + 16%N				
Grade	Cr	Mo	N	PRE
316L	18	2	-	24
317L	18	3,5	0,1	31
SAF 2205	22	3,1	0,2	35
2RK65 (904L)	20	4,5	-	35
254SMO	20	6	0,2	43
SAF 2507	25	4	0,3	43
SAF 2707 HD	27	5	0,4	49

Critical Temperatures

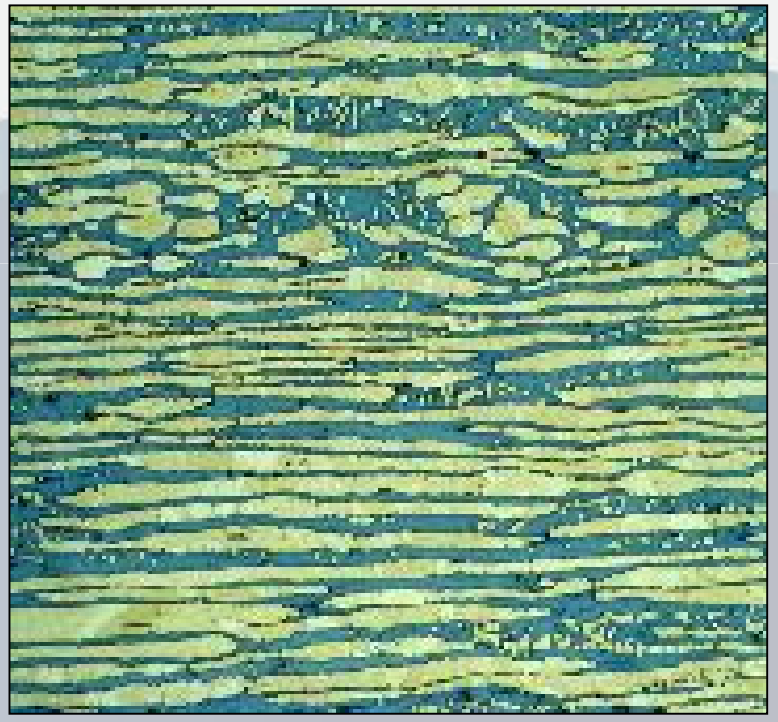
- Above T_{crit} corrosion mechanism starts
  - CPT = Critical Pitting Temperature
  - CCT = Critical Crevice Temperature
- Determined by ASTM G48
  - CPT – Practice C
  - CCT – Practice D
- Comparison criteria – not selection!
- CPT > CCT – look for crevices

CPT and CCT


Temperature (°C)
CPT (°C)
CCT (°C)
*25Cr - 3Mo - .2N
90
80
70
60
50
40
30
20
10
904L
Sandvik SAF 2205
25 Cr Duplex*
6Mo+N austenitic
Sandvik SAF 2507
Sandvik SAF 2707 HD
97.5

Duplex Stainless Steels

- Ferritic-Austenitic structure (~50% each)
- Duplex Fe-Cr-Ni-Mo grades
  - SAF2304, SAF2205
  - SAF2507, SAF2906
  - SAF2707 HD, SAF3207 HD
- High yield strength (2x Ferritic)
- Good ductility - easy to form 30% elongation.
- Good impact strength
- Excellent weldability
- High corrosion resistance



Duplex vs. Superaustenitics

Corrosion resistance

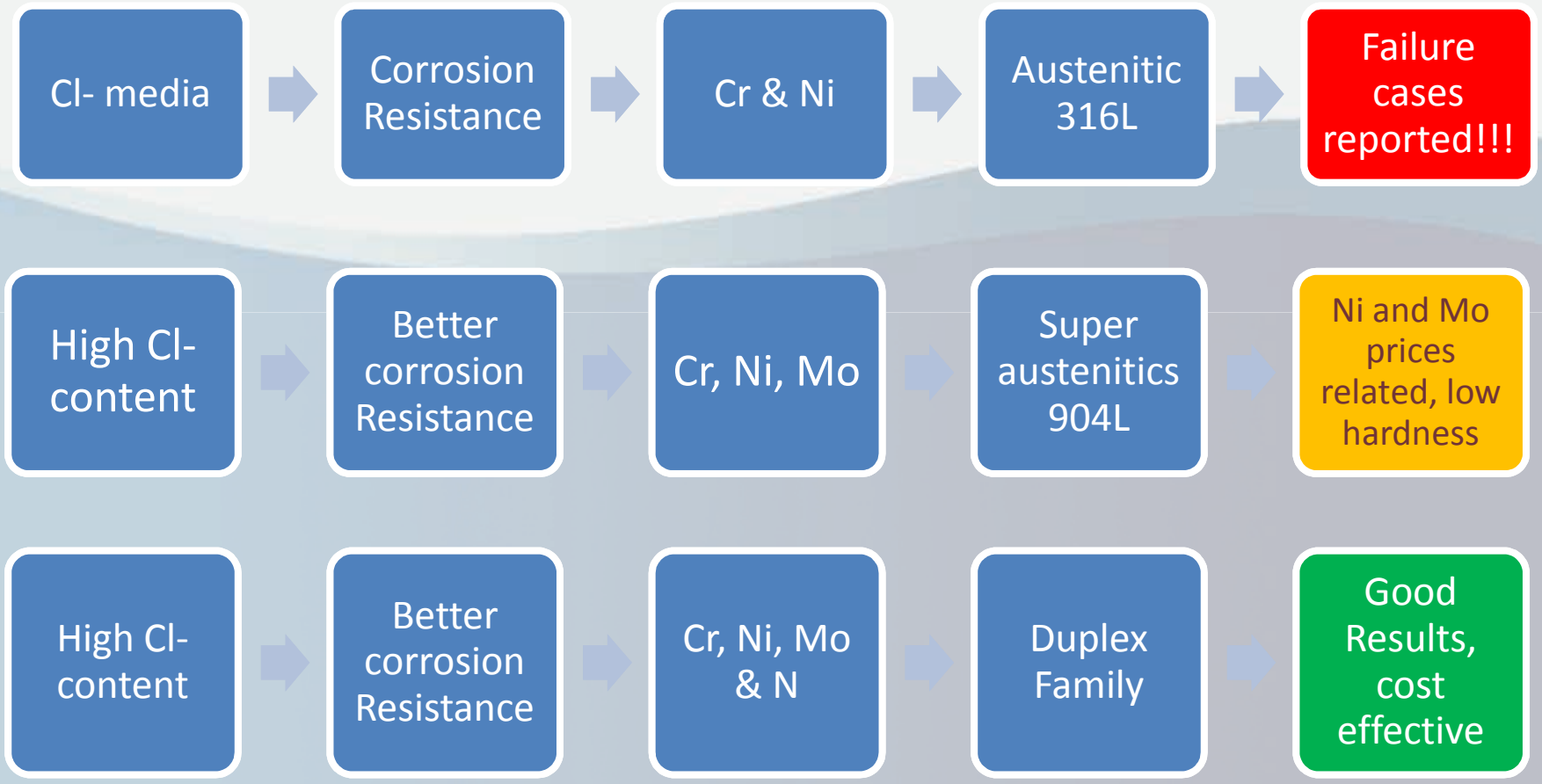
Chemical Composition - PRE					
Grade	Cr	Mo	N	Ni	PRE
SAF 2205	22	3,1	0,2	5	35
2RK65 (904L)	20	4,5	-	25	35
254SMO	20	6	0,2	18	43
SAF 2507	25	4	0,3	7	43
SAF 2707 HD	27	5	0,4	6,5	49

Duplex vs. Superaustenitics

Mechanical properties

Grade	Hardness (HV)	Yield Strength (MPa)	Tensile Strength (MPa)
2RK65	160	220	520
SAF 2205	286	485	680
254SMO	180	310	675
SAF 2507	318	550	800
SAF 2707 HD	336	700	1000

Material Selection



Selection of Duplex grades

- Chemical composition: ASTM A 751
- Phase distribuition: ASTM E 562
- Intermetallic phases: ASTM A 923
- Hydrostatic test and ultrasonic test
- Corrosion resistance:
  - Pitting and Crevice: ASTM G 48
  - Stress Corrosion Cracking: ASTM G 36
- Average PRE = (Austenite PRE + Ferrite PRE)/2
- **Sandvik** guarantee both PRE´s equivalent (±1)

Conclusions

- Desalination alternative needed
- Corrosion resistant materials
- Duplex grades appear as cost-effective solution
  - SAF 2707 HD, higher PRE and Hardness
- Correct duplex selection leads to better performance and lifetime