Common Stainless Steel Corrosion Problems in the Water & Desalination Industries

Why They Happen & How We Can Avoid Them

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   g. Long Beach Water Dept.
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   i. San Diego Cty. Water Auth.
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The Challenge

vcstar.com
VENTURA COUNTY STAR

Printer-friendly story
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Pump problems keep Oxnard desalter offline

By Gretchen Wenner

Monday, March 18, 2013

There's a hole where it shouldn't be. That much is for sure.

But Oxnard water officials might never know exactly what went wrong with two relatively young pumps at the city's $30 million desalter plant.

"Corrosion science is so complicated," said Anthony Emmert, water resources manager. "It's basically as predictable as the weather."

The SST Challenge

1. Pick a *high enough* grade of steel to provide the required protection *but not more* than you need.
   a. 6 grades of steel.
   b. 120+ compositions.
2. Assemble the piping and other equipment correctly.
3. Operate it properly.

The Problem – Info Is Scattered

Guidance on Selecting Materials Is Not In One Place

AWWA Standard	Description
C220	Stainless-Steel Pipe' ½-inch (13 mm) and Larger
C221	Fabricated Steel Mechanical Slip-Type Expansion Joints
C223	Fabricated Steel and Stainless Steel Tapping Sleeves
C226	Stainless-Steel Fittings for Waterworks Service, Sizes ½-inch – 72-inch (13 mm – 1,800 mm)
C227	Bolted, Split Sleeved Restrained and Non-restrained Couplings for Plain End Pipe
C228	Stainless Steel Pipe Flanges for Water Service, Sizes 2-inch – 72-inch (50 mm – 1,800 mm)
C230	Stainless Steel Full Encirclement Repair and Service Connection Clamps

Material Specs Are Similarly Dispersed

ASTM Standard	Description
A240	Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip for Pressure Vessels and for General Applications
A312	Seamless and Welded Austenitic Stainless Steel Pipes
A403	Wrought Austenitic Stainless Steel Piping Fittings
A774	As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures
A778	Welded, Unannealed Austenitic Stainless Steel Tubular Products
A789	Seamless and Welded Ferritic/Austenitic Stainless Steel Tubing for General Service
A790	Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe
A813	Single or Double Welded Austenitic Stainless Steel Pipe
F593	Stainless Steel Bolts, Hex Cap Screws, and Studs
F593	Stainless Steel Nuts

And So Are Material Finish Specs

ASTM Standard	Description
A380	Cleaning, Descaling and Passivation of Stainless Steel Parts, Equipment and Systems
A967	Chemical Passivation Treatments for Stainless Steel Parts

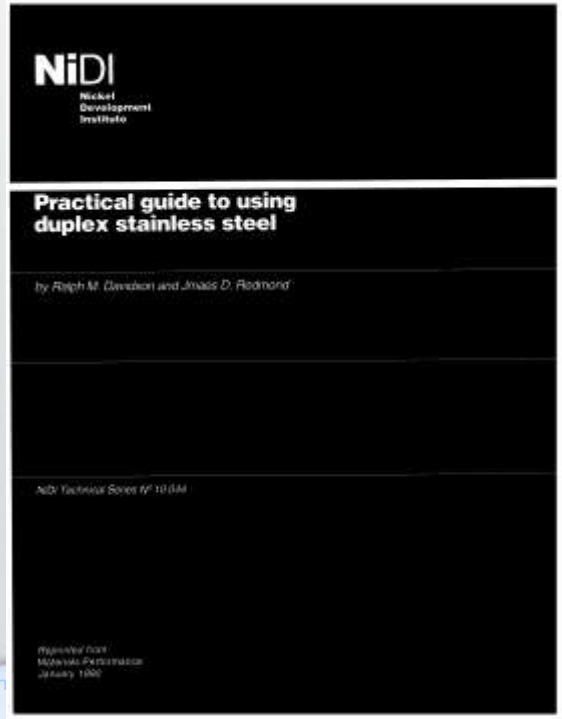
The Solution:

"Develop a guidance document for engineers and consultants to help them properly specify the type of stainless steel most appropriate for a given water system and/or water treatment chemical system application."

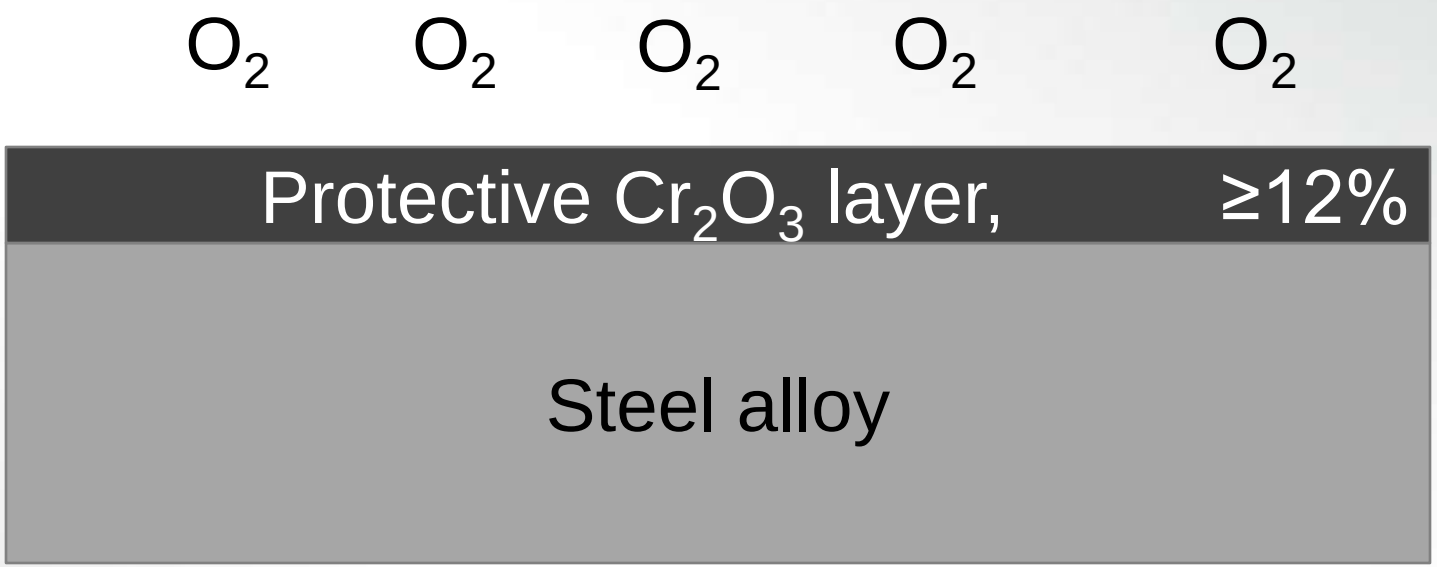
Pull the info together that explains how to pick the right steel and how to use it properly.

The Approach

1. Summarize the literature.
2. Capture what people are experiencing.
3. Fill in data gaps.
4. Develop formal guidelines.



What Is Stainless Steel?



A metallic alloy whose Cr content is >12% by weight.

For austenitic & duplex SS, Cr_2O_3 layer forms a corrosion-resistant barrier on the surface.

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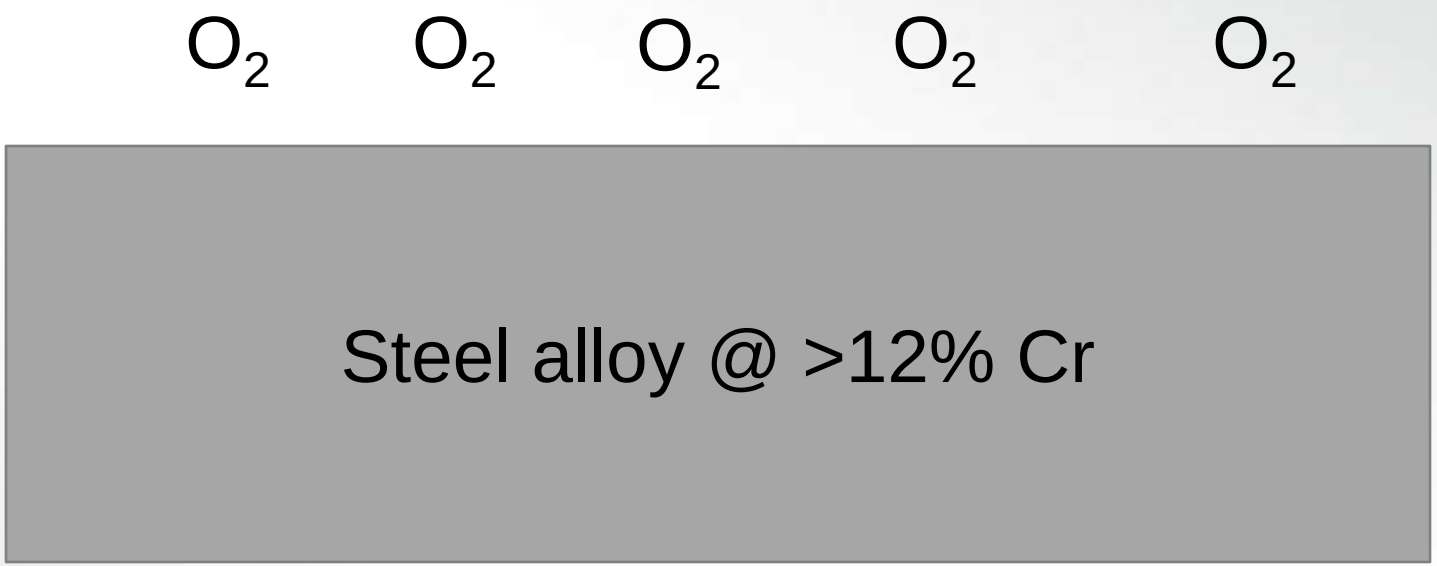
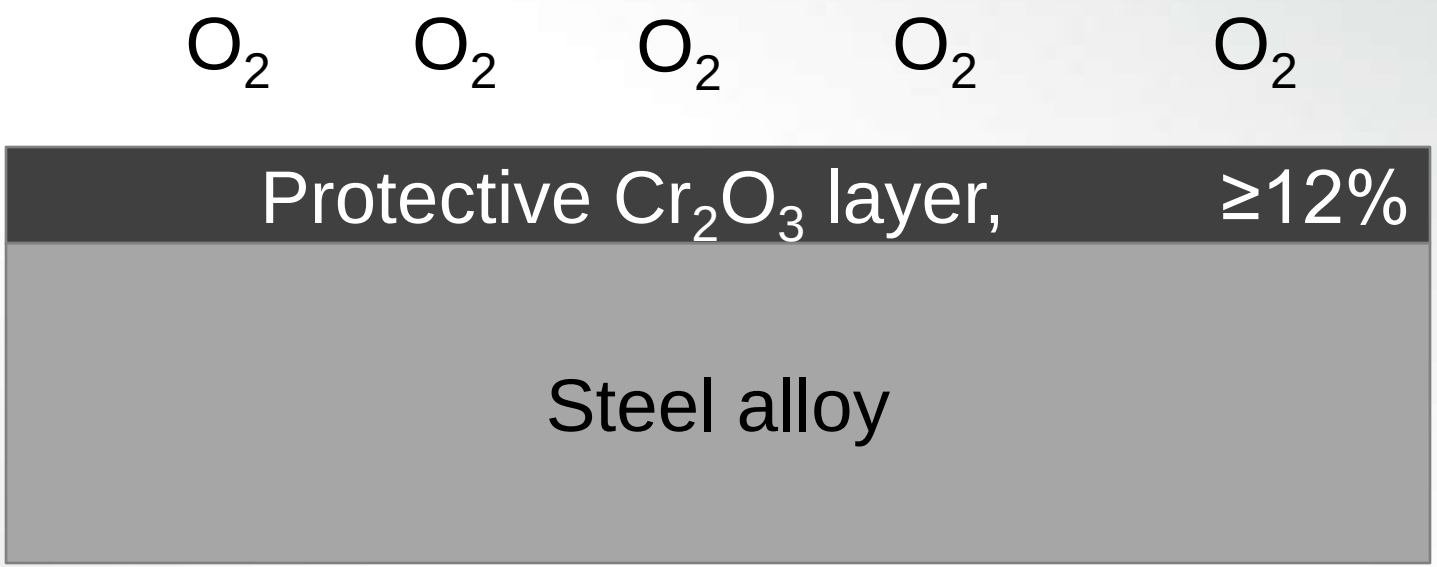


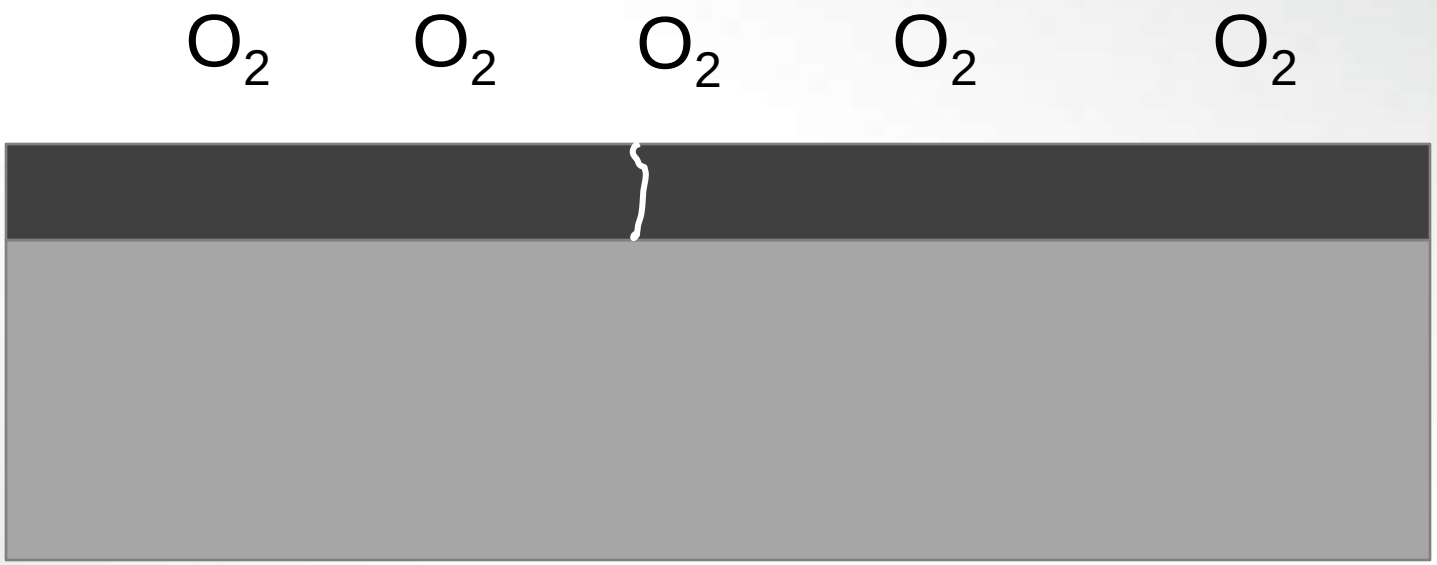
Others, e.g., martensitic and ferritic,
don't have a Cr coating.

What Is Stainless Steel?

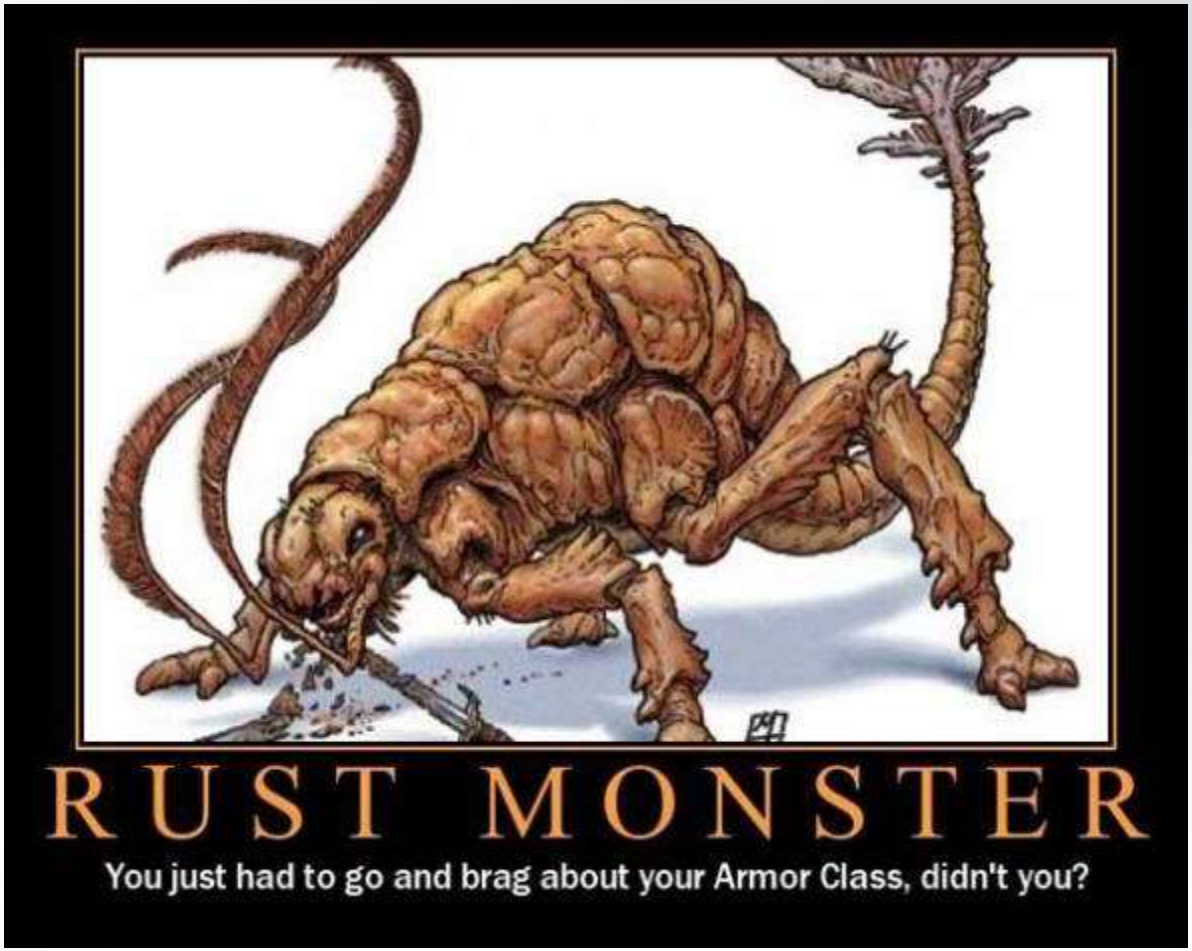


The basic alloys used in water treatment are 304/304L and 316/316L austenitic stainless steels.

How Does Corrosion Occur?



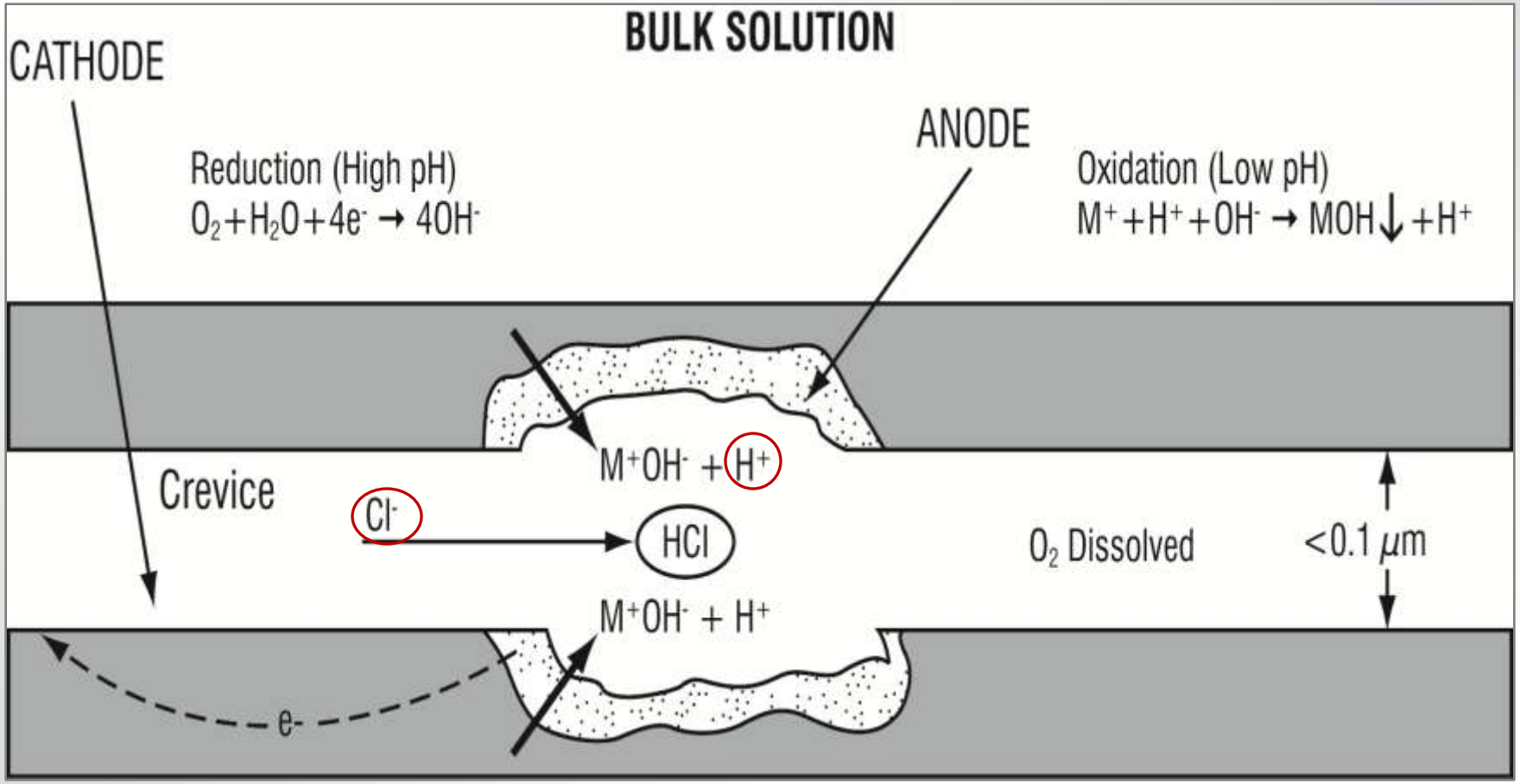
The surface becomes damaged, dirty, or otherwise compromised.



Warmer temperatures, chlorine, and chlorides speed this process up.

SPECIAL CHALLENGES FOR DESAL

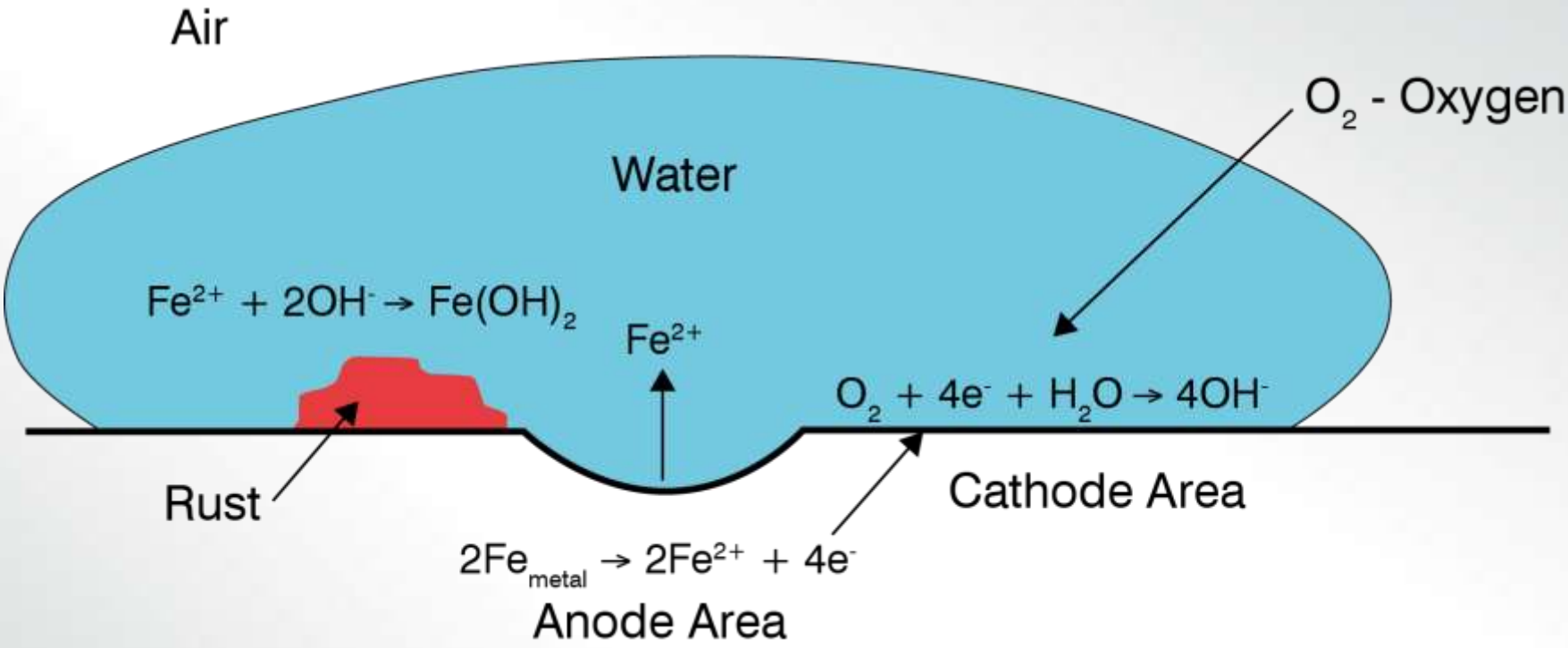
Crevice Attack



An electrochemical cell forms in a tight M-to-M joint.

The crevice gap dimension is critical. Cl- is a catalyst.

Pitting Attack



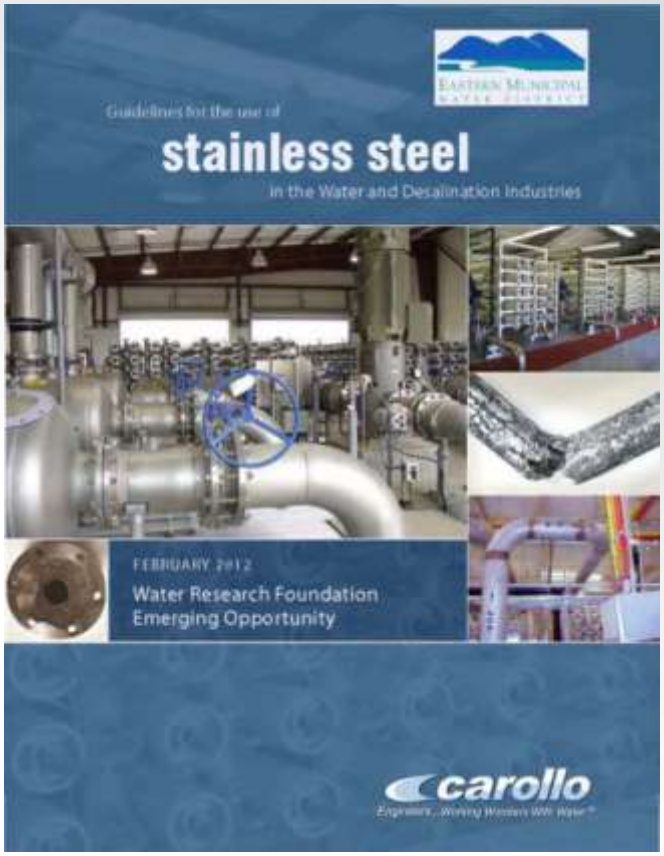
- Cl- is attracted to anode, form M-Cl, pH at bottom drops, process accelerates.
- Process speeds up with increasing Cl^-, T.

MIC Can Be a Significant Problem

1. Like crevice corrosion attack.
   a. Bacteria form a biofilm.
   b. Becomes a tubercule.
   c. Anodic and cathodic sites develop and a corrosion cell is formed.
   d. Aggressive chemicals can accumulate and accelerate the rate of corrosion.

Bushman & Associates, http://www.bushman.cc/corrosion_photos.html

Mitigating Corrosion



STEP 1 – FIGURE OUT WHAT MATERIAL YOU NEED

Cutoffs Where Crevice Corrosion Aided by Cl^- &/or OCl^- at Ambient T. Is Unlikely

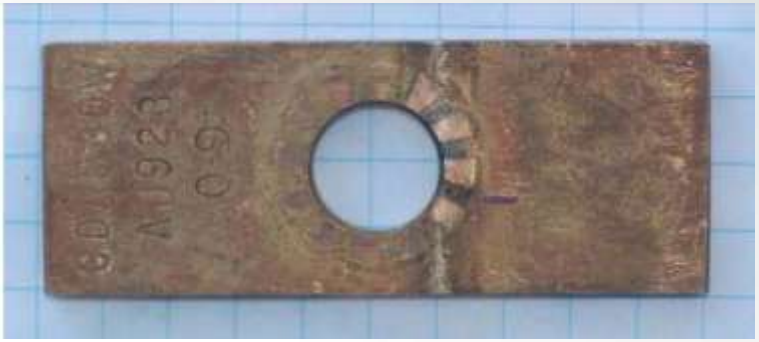
Material	Concentration of Free Chlorine in Feed Water		
	0 mg/L	2 - 3 mg/L	3 - 5 mg/L
	Chloride Concentration		
304/304L stainless steel	< 250 mg/L	<100 mg/L	-
316/31			
Dup			
Dup Alloy AL-6XN Ferralium 255	15,000 mg/L		
Zeron 100 Ferralium 255 Alloy 654Mo	< 15,000 and up to 20,000 mg/L	-	-
Zeron 100; 654SMO	> 20,000 mg/L		

These are rules of thumb. pH, temperature, aeration, high free chlorine, high chloride & chlorine mixes will influence the best choice.

Duplex are best

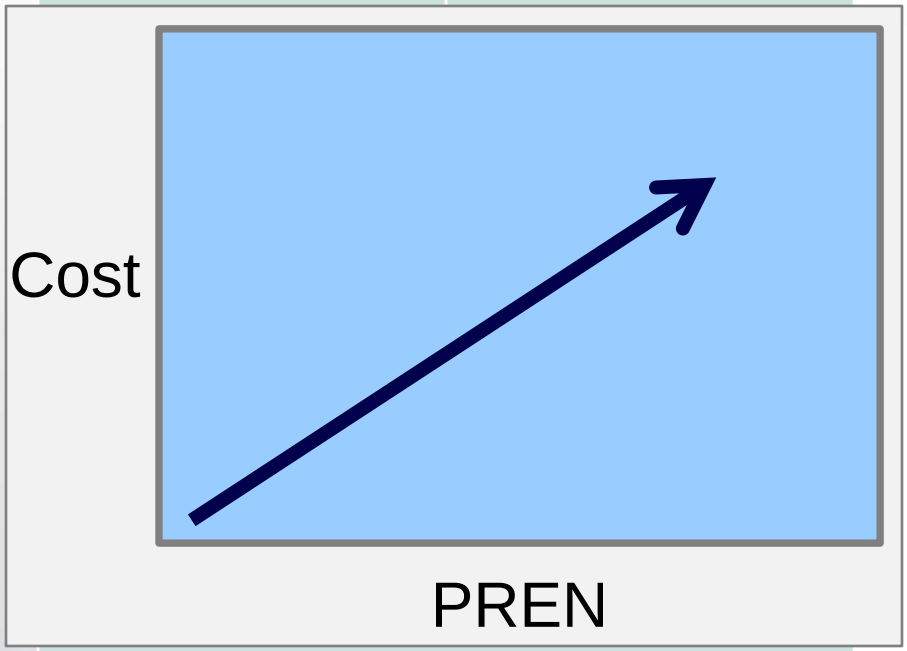
When Choosing a SST Alloy, PREN Is a Valuable Guideline

1. PREN = Pitting Resistant Equivalent Number



PREN = % Cr + 3.3(% Mo) + 16(%N)

TYPE	PREN
AUSTENITIC STAINLESS STEEL	
304/304L	19
LDX2101	22
AL6XN	40
254 SMO	43
654 SMO	48
7% Mo	57



PREN Provides a General Indication, Test Data Provides Empirical Support

1. ↑PREN = ↑Pitting resistance
   a. ↑ Mo, ↑ N, ↑ Cr
2. Combine with test data (ASTM G48 & G150)
   a. E.g., "under X WQ, corrosion of SST followed PREN values."

There Is Limited Lab Data on the Effect of Chlorine on SST Corrosion

1. Type 304/304L becomes vulnerable @ 3-5 ppm.
2. High conc. of chlorine ⇒ use higher alloyed material.

OCl - Resid. (mg/L as Cl_2)	Maximum Depth of Attack (mm)			
	Type 304 SS (PREN = 19)		Type 316 SS (PREN = 25)	
	Base Plate	Crevice	Base Plate	Crevice
0 [1]	0	0	0	0
0.8-1 [1]	0	0	0	0
2.0 [1]	0	0	0	0
3 - 5 [2]	<1	4-14	0	1 - 5

Notes:

1 Water contained 23 mg/L of chloride.

2 Water contains 790 mg/L of chloride.

Source: The Nickel Institute.

Mitigating Corrosion

STEP 2 – LEARN FROM FIELD EXPERIENCES

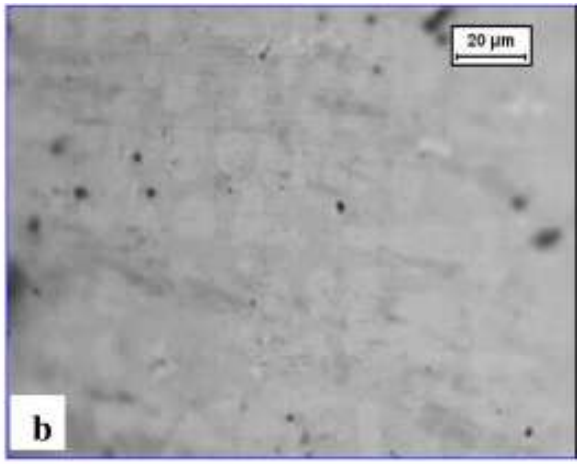
The "Bad Actors"

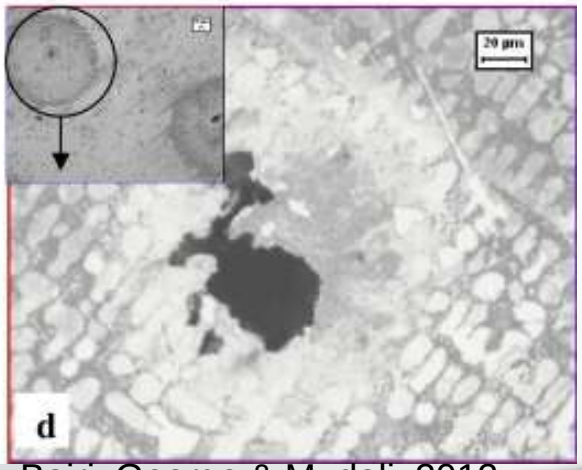
1. Problematic welds & improper passivation.
2. Scratches & surface contamination.
3. Dissimilar metals (i.e., galvanic corrosion).
4. Paint/oil/tape.
5. MIC.
   a. Use & disposal of construction test waters.
   b. Sticky sediments.

Design or Fabrication Mistakes Can Be Sources of Crevice Attack

1. Human-mediated
   a. Stationary O-rings.
   b. Gasket surfaces.
   c. Non -metallic connectors.
   d. Poor root pass pipe welds.
   e. Skip welds.
   f. Paint, oil/grease, tape.
   g. Bolted joints.

Design or Fabrication Mistakes Can Be Sources of Crevice Attack





Bairi, George & Mudali. 2012. *Corrosion Science*, 61:19-27.

1. MIC
   a. Crustaceans.
   b. Sticky sediments.
   c. Bacterial colonies.
   d. Sediment deposits.

http://www.pairodocspro.com

Don’t Field Weld

1. The best QC is in a pipe fabricator’s shop.
   a. Plan out the pipe fabrication.
   b. Field verify dimensions.
   c. Then build it.

Note: This actually saves contractors money by not having to mobilize a certified welding crew.

Note: Where field welding is allowed, purge inside the pipe with an inert gas (e.g., Ar) and passivate the welded area (inside and out) – *exact procedures may vary with material type.*

Write Careful Specs and Require They Be Followed

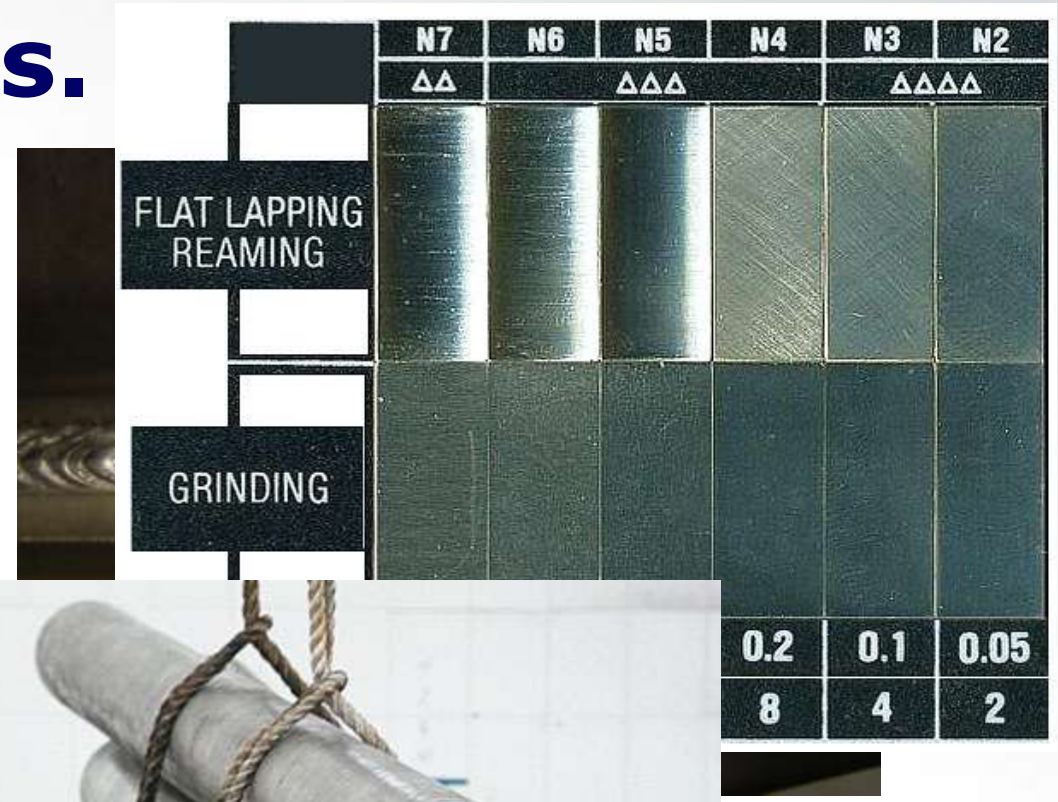
1. Specify shipping procedures:
   a. Ship the piping material on pallets with the ends capped off with non-metallic covers.
   b. Foam and shrink wrap surfaces.
   c. Piping should not rub against each other or other non-SS surfaces.

Write Careful Specs and Require They Be Followed

2. Specify storage and handling procedures:
   a. Piping should be stored on pallets, not on ground.
   b. No iron contaminants (grinding or weld slag) should come into contact with piping.
   c. Lift with nylon straps, not metallic chains.
3. Specify testing conditions for piping to incl:
   a. Drain and dry piping so that stagnant water is not present.
   b. Flush and drain high dose chlorinated solutions from piping immediately after disinfection testing.

Other Important Considerations.

1. Approaches to welding.
2. Parts fabrication.
3. Surface finishes.
4. Approaches to passivation & pickling.



Take-Home Message

1. Specifying SS is important but not always well understood in our industry.
2. Critical considerations include:
   a. Nature of piping environment.
      - Cl^- OCl^-, T.
   b. Proper handling and installation.
      - Keep things clean.
      - Don’t scratch the pipes.
   c. Good maintenance to control MIC.
3. There’s a lot of information to sift through.

A step-through guidance document will help us make the right decisions.

For Next Time

1. Guidelines.
   a. Selection of materials.
   b. Specification of materials.
      - Preparation.
      - Installation.
   c. Operations & maintenance.

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