

REINHOLD ENVIRONMENTAL Ltd.



**2013 APC Round Table
& Expo Presentation**

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Corrosion of FGD Stainless Steels

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If you have a question during this presentation, raise your hand and we will discuss it rather than waiting until the end of the presentation

Stainless Steel vs. Nickel Alloys

Composition of Representative FGD Alloy Materials

Alloy		Nominal Composition, weight %						
Common Name	UNS Number	Fe	Cr	Ni	Mo	Cu	N	Others
316L SS	S31603	Bal.	17	12	2.5	-	-	-
317L SS	S31703	Bal.	19	13	3.5	-	-	-
317LM SS	S31725	Bal.	19	16	4.5	-	-	-
317LMN SS	S31726	Bal.	19	16	4.5	-	0.15	-
317LN SS	S31753	Bal.	19	13	3.5	-	0.16	-
254 SMO	S31254	Bal.	20	18	6.3	0.8	0.2	-
2205 Duplex	S31803	Bal.	22	5.5	3.0	-	0.14	-
255 Duplex	S32550	Bal.	26	5.5	3.4	2.0	0.18	-
Zeron 100	S32760	Bal.	25	7	3.5	1.0	0.25	-
904L	N08904	Bal.	21	26	4.5	1.5	-	-
904hMo	N08925	Bal.	20	25	6.5	1.2	0.15	-
1925hMo	N08926	Bal.	21	25	6.4	0.9	0.22	-
AL-6X	N08366	Bal.	21	25	6.5	-	-	-
AL-6XN	N08367	Bal.	21	25	6.5	0.8	0.22	-
JS-700	N08700	Bal.	21	25	4.7	0.5	-	-
20	N08020	Bal.	20	35	2.5	3.5	-	0.5Cb + Ta
20 Mo-6	N08026	Bal.	24	35	5.9	3.0	-	-
825	N08825	Bal.	22	42	3.0	2.3	-	0.9Ti
G	N06007	20	22	Bal.	6.5	2.0	-	2.2Cb + Ta, 1.0W, 2.5Co
G-3	N06985	20	22	Bal.	7.0	2.0	-	0.5Cb + Ta, 1.5W, 5.0Co
H-9M	N06920	19	22	Bal.	9.0	-	-	2.0W, 5.0Co
Allcorr	N06110	-	31	Bal.	10.0	-	-	2.0W
625	N06625	5.0	22	Bal.	9.0	-	-	3.7Cb + Ta
C-276	N10276	5.5	15	Bal.	16.0	-	-	3.8W, 2.5Co
C-4	N06455	3.0	16	Bal.	16.0	-	-	0.7Ti, 2.0Co
C-22	N06022	3.0	22	Bal.	13.0	-	-	3.0W, 2.5Co
59	N06059	1.5	23	Bal.	16	-	-	-

18-8 Family

- The most common member of this family (304 SS) contains 18% chromium and 8% nickel
- They are austenitic stainless steels which are non magnetic

Active Surface

- A clean metal surface is active in that it will react with the environment around it to form various chemical compounds on its surface depending on what is in the surrounding environment

Active Surface (cont.)

- There are various ways to create an active surface
 - Pickling
 - Electropolishing
 - Grinding
 - Abrasive Blasting
 - Mechanical Scraping

Passive Surface

- A passive surface will not react with or change because of the surrounding environment
 - If the surrounding environment changes to conditions that are beyond the parameters required by the passivity, the surface can become an active surface once again

Passive Surface (cont.)

- On austenitic SS a natural passive chromium-rich oxide film forms on the metal surface
- This film is very thin (**1-5 nanometers**)
- It is strongly adherent and chemically stable under conditions that provide sufficient oxygen to the surface

Passive Surface (cont.)

- The key to the durability of SS is that this film will normally self repair if it is damaged.



What Prevents Passivation

- High flow/abrasion areas where the passive film is constantly removed
- Oxygen poor areas (such as under deposits)

What Prevents Passivation (cont.)

- Iron embedded in the surface of the base metal
 - Welding, cutting or grinding carbon steel above a SS surface
 - Using carbon steel tools on SS
 - Using grinding wheels or files that have previously been used on carbon steel on SS
 - Scaffolding feet, shovels, Bobcat buckets, etc. abrasion on a SS vessel floor

What is the difference between 317 and 317LMN

- L – a carbon content less than .03% prevents carbide precipitation during welding and thus increases corrosion resistance
- M – at least 4% molybdenum to improve pitting and crevice corrosion resistance

What is the difference between 317 and 317LMN (cont.)

- N – at least .15% nitrogen which helps form Austenite, increases the Austenite stability, improves yield strength and increases resistance to pitting corrosion

Welding

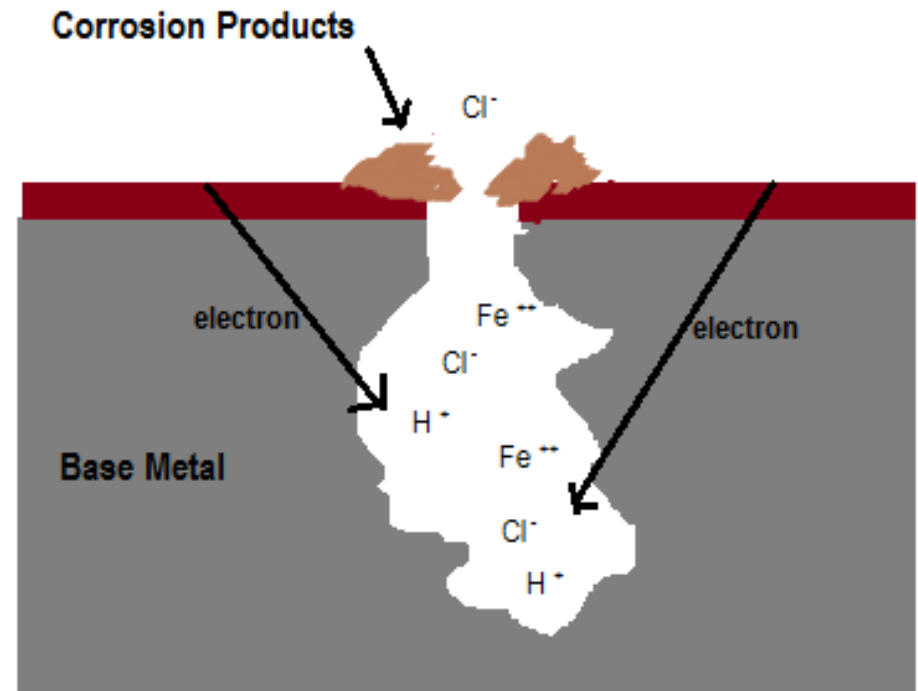
- Welding destroys the passive layer and leaves a mixture of all sorts of oxides on the SS surface
- After welding, the affected area should be pickled to restore a clean active metal surface (there are pickling pastes that can be applied to the welded area)

Welding (cont.)

- After pickling, the weld affected area can be left to passivate naturally or passivation chemicals can be applied to accelerate the passivation process

Chlorides/(Fluorides)

- Chlorides can penetrate the passive layer and attack the base metal
- Chloride levels can concentrate under scale deposits



Chlorides/(Fluorides)(cont.)

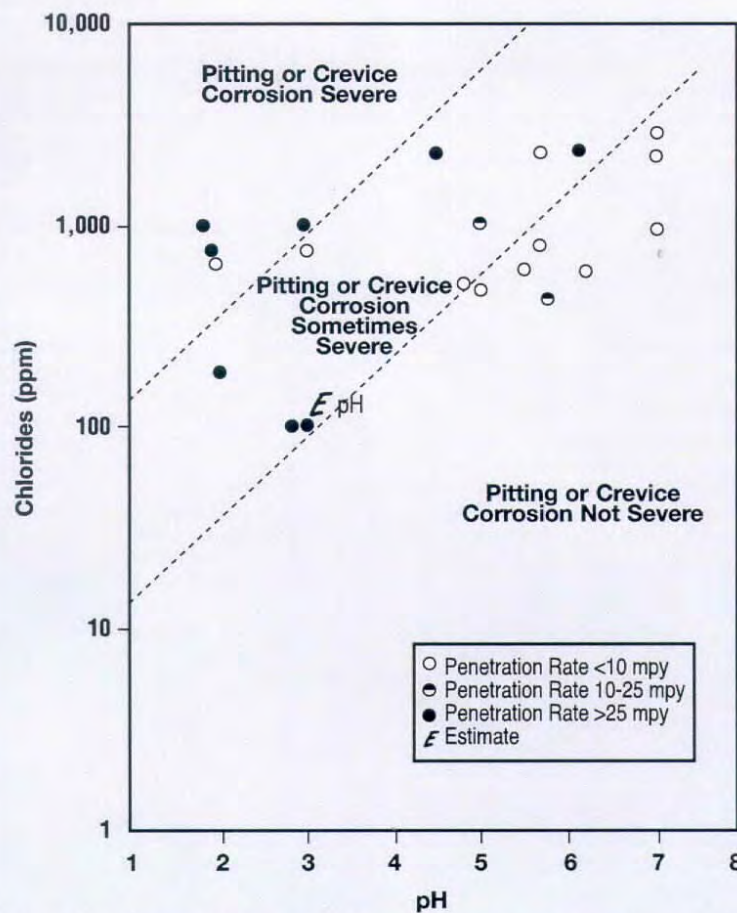
- Molybdenum increases the resistance of the passive film to chlorides
- Metal suppliers have created austenitic SS grades with a minimum of 6% molybdenum which are commonly referred to as “super austenitic” SS

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Effect of pH and Cl ions on the localized attack of Type 317L stainless steel in SO₂ scrubber environments⁵¹



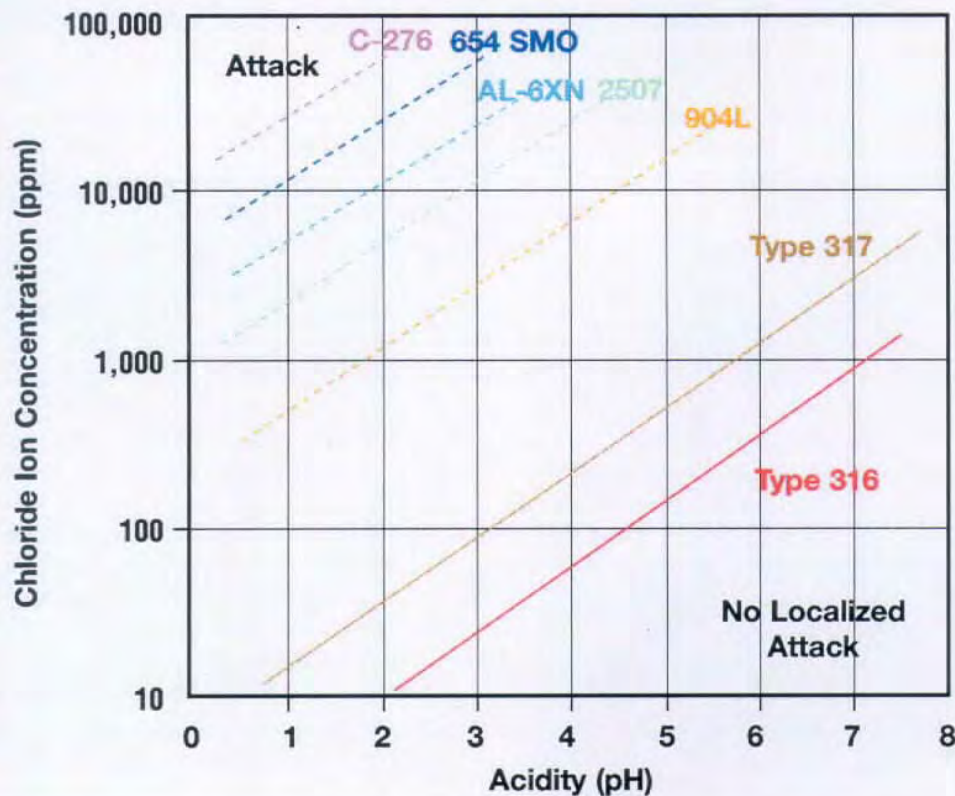
Dashed lines approximate attack. Some points represent as many as 5 tests.



GUIDELINE STAINLESS STEEL AND NICKEL ALLOY SELECTION FOR FGD EQUIPMENT

		MILD		MODERATE		SEVERE		VERY SEVERE		
CHLORIDE ppm		100	500	1,000	5,000	10,000	30,000	50,000	100,000	200,000
MILD	pH 6.5	TYPE 316 L STAINLESS STEEL		TYPE 317 LMN			NICKEL ALLOY 625 ETC			
	MODERATE	pH 4.5			STAINLESS STEEL	SUPER DUPLEX STAINLESS STEEL		SUPER AUSTENITIC STAINLESS STEEL	NICKEL ALLOY C276 ETC	
SEVERE	pH 2.0	TYPE 317 LM STAINLESS STEEL	22% Cr DUPLEX STAINLESS STEEL		25% Chromium Stainless Steels		6% Molybdenum Stainless Steels			
VERY SEVERE	pH 1.0	TYPE 317 LMN STAINLESS STEEL	SUPER AUSTENITIC STAINLESS STEEL			NICKEL ALLOY 625 ETC		6% Molybdenum Stainless Steels		

Approximate service limits for stainless steels and nickel-base alloys in flue gas condensates and acid brines at moderate temperatures [60-80°C (140-176°F)]^{51,52,53}



Duplex Stainless Steel

- The duplex SS has both austenitic and ferritic grain structures.
- The austenitic grains and the passive layer give it general corrosion resistance
- The ferritic grains make it more resistant to chloride/fluoride attack

Duplex SS Corrosion

- In papers presented by B&W at the last two APC Roundtables, they indicate that under certain conditions of ORP, the manganese oxide in the slurry precipitates and forms a deposit on the surface of the duplex SS

Duplex SS Corrosion (cont.)

- They have identified two types of corrosion under this deposit
 - Pitting attack cause by high fluoride concentrations (minor attack)
 - Galvanic attack caused by the manganese oxide deposit (major attack)

Nickel Alloys

- Nickel alloys with their high alloy content are resistant to corrosion because of their constituents, are resistant to chloride pitting and do not rely on a passive film for corrosion resistance, so they can survive in areas where the stainless steels cannot

Any unanswered questions?