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Scrubber material selection and fabrication challenges.

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www.sverdrupsteel.com

CONTENT OF PRESENTATION

- Scrubber designs
- Material selection
- Preventing corrosion issues
- Challenges in scrubber production
- Quality verification

Introduction

The life span of a marine scrubber system will depend significantly on the chosen material, its corrosion resistance and the manufacturing process performed.

When using in-appropriate stainless steels or alloys, the composition of the exhaust gases may cause corrosion that leads to damages of the scrubber in a short period or to a complete failure of the system.

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Scrubber is one solution

Sea water scrubbers – Open loop scrubbers

Fresh water scrubbers – Closed loop scrubbers

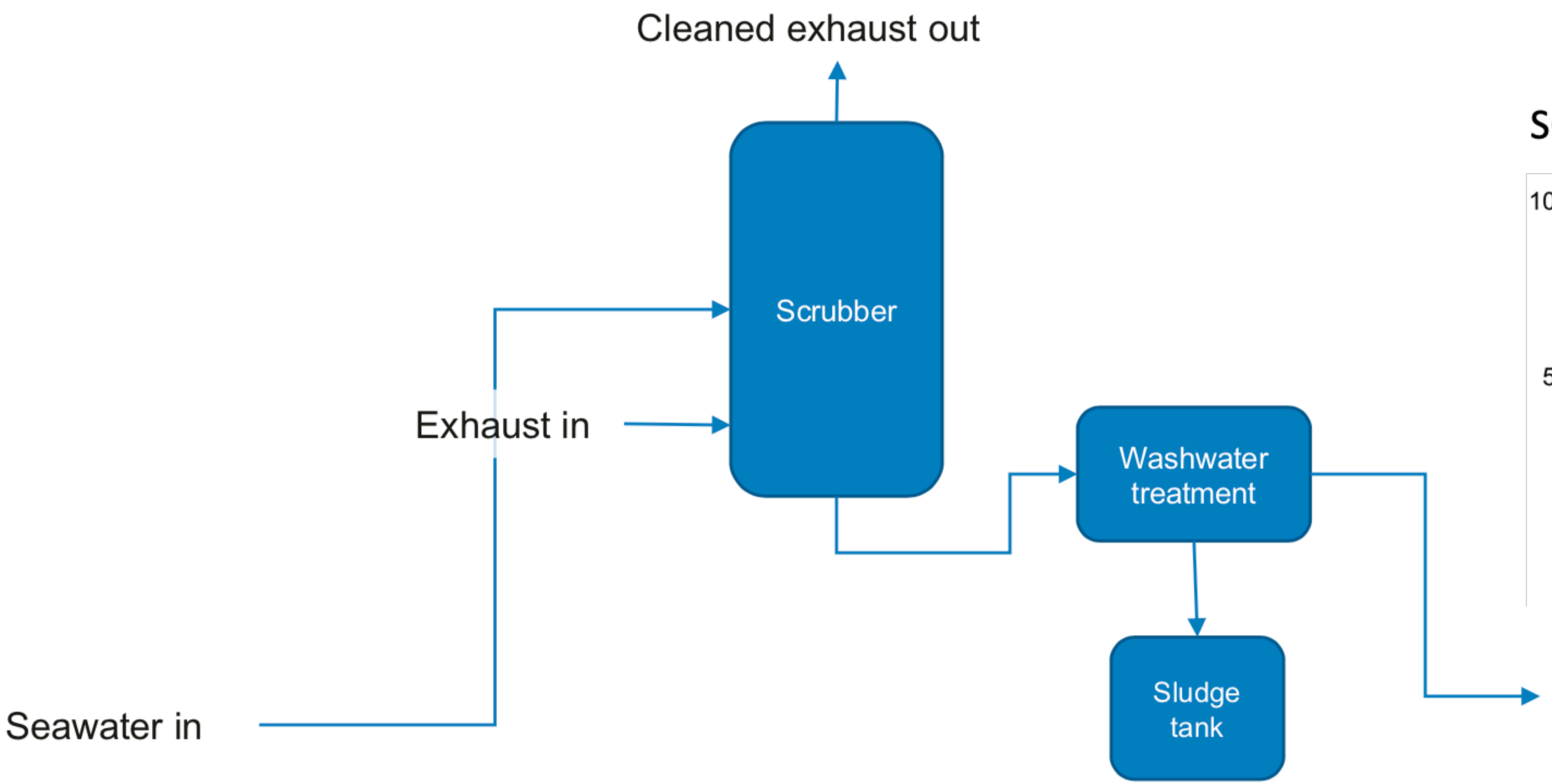
For less salty environments: Lakes and e.g. Baltic Sea

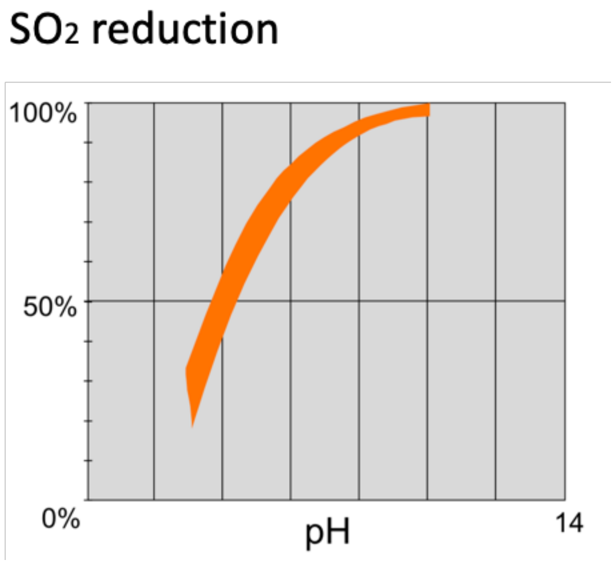
Fresh water and sodium hydroxide (caustic soda)

Hybrid scrubbers –

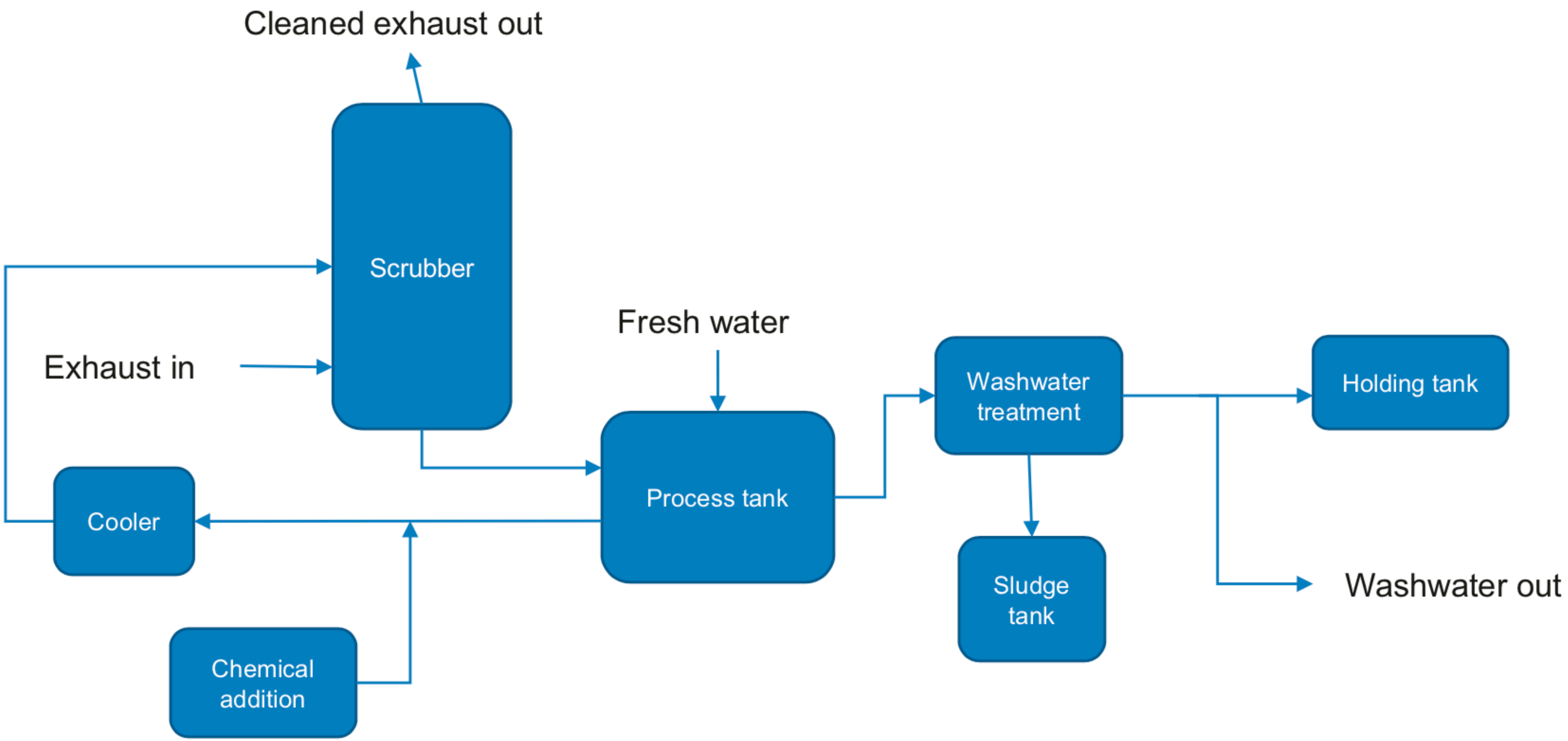
Operates in both fresh and salt water environment

Open loop scrubber system





Closed loop scrubber system



Hybrid scrubber system

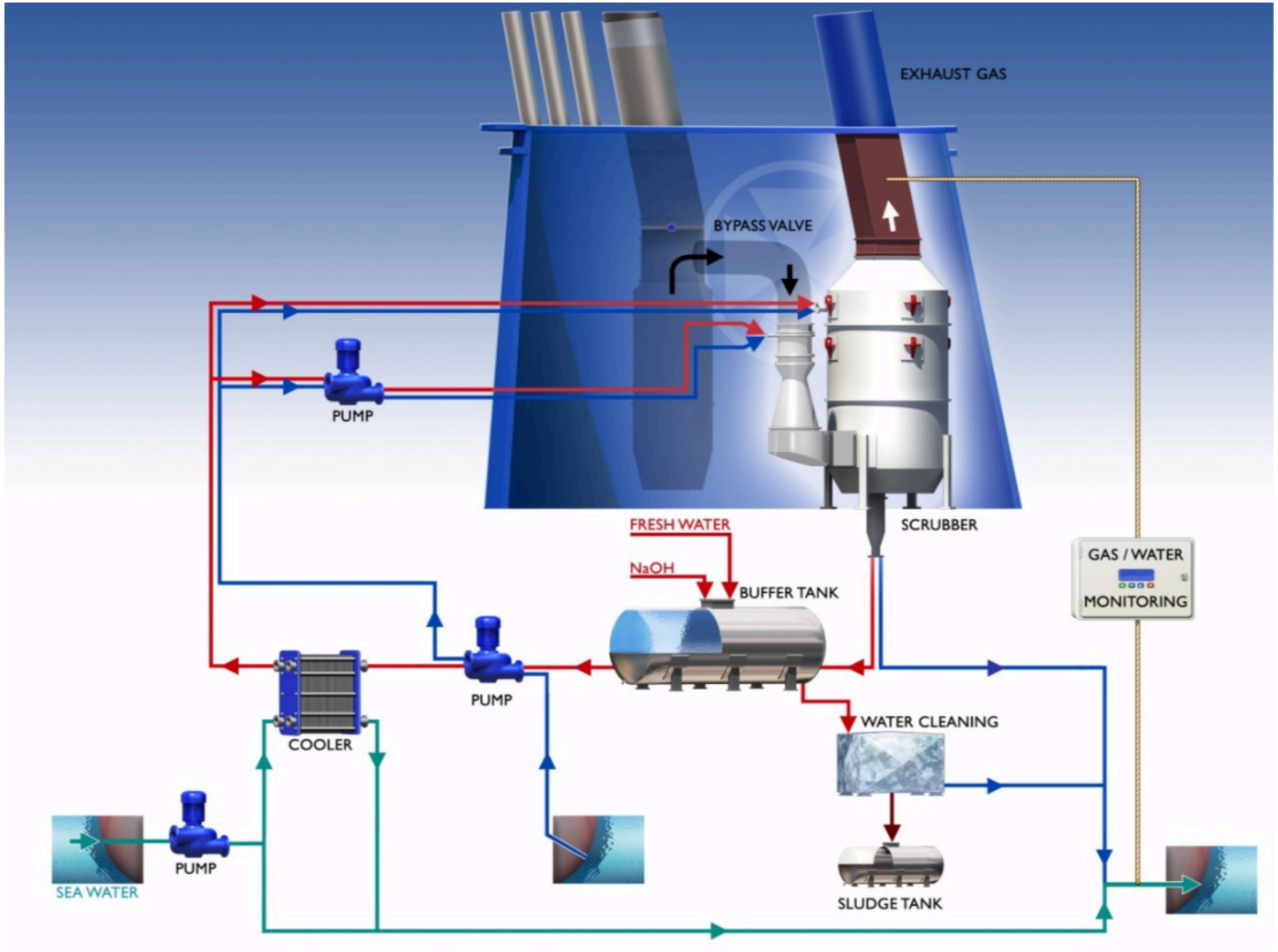


Figure 3. Hybrid System (Aalborg Industries)

Scrubber industrial challenges

Scrubber Engineering design

Design

Steel producer with good material production track record (Approved manufacturer according to NORSOK M650/ ISO 17782..)

Choosing appropriate manufacturing partner

- Experience in manufacturing of high alloy stainless products
  - Handling, rolling, cutting, welding, DT/ NDT, pickling..

Scrubber material challenges

The lower portions of the scrubber (especially the open loop-type) may have a high concentration of acid and chlorides.

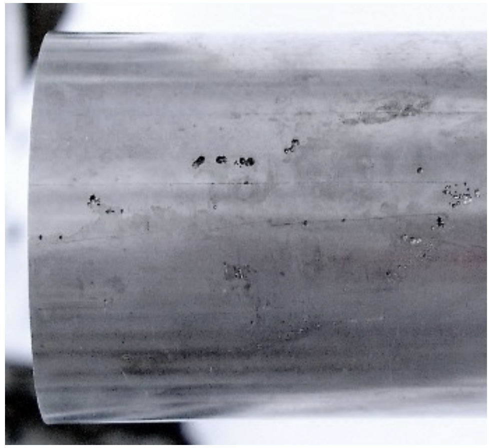
Scrubbers suitable for dry operation and wet scrubbers without a facility for bypassing exhaust gas when the wash-water system is not in operation, would experience higher operating temperatures and therefore this limits the materials selection to high temperature acid and chloride resisting alloys; typically nickel alloys.

Above the lower portions of the scrubber unit a less corrosion resistant stainless steel is often used.

Preventing corrosion issues

- Understanding of operational conditions, mild to severe conditions
  - Temperature : 40 – 80°C / 250 - 350 °C
  - pH of sea water = 7.5 – 8.4,
  - Alkalinity = ability to resist change in pH
  - Chloride content : ≥ 20.000 ppm
  - Low pH (2–4) during some of the operation
  - Addition of Sodiumhydroxide (NaOH) or not

Pitting corrosion



Crevice corrosion

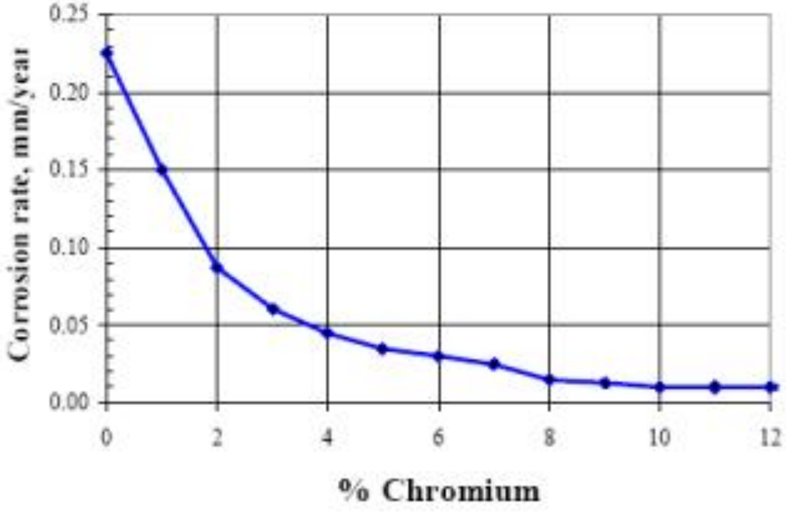
Stainless steel

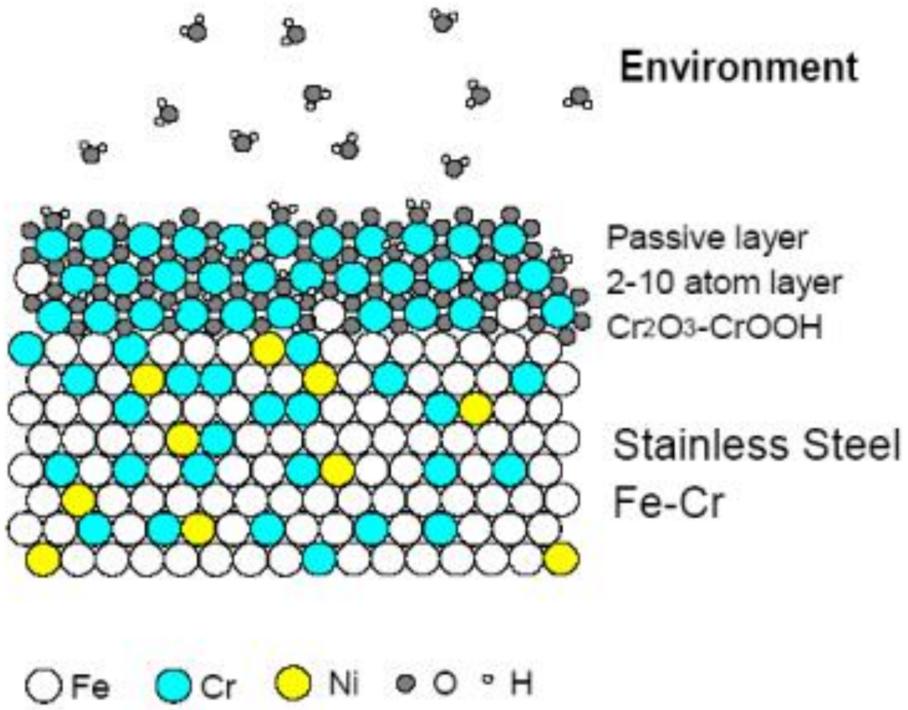
>10,5 % Cr

↳ Passiv layer

↳ Corrosion rate drops

Oxygen is necessary to maintain the passive film of
2-3 nm = 0.000002mm - 0.000000008"





Corrosion of stainless steel

Uniform corrosion

Crevice corrosion

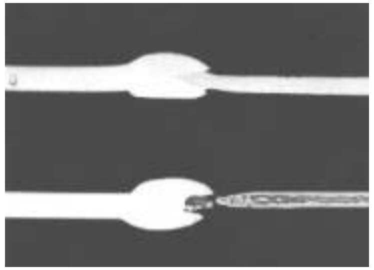
Stress corrosion

Fatigue corrosion

Intergranular corrosion

Galvanic corrosion

Atmospheric corrosion



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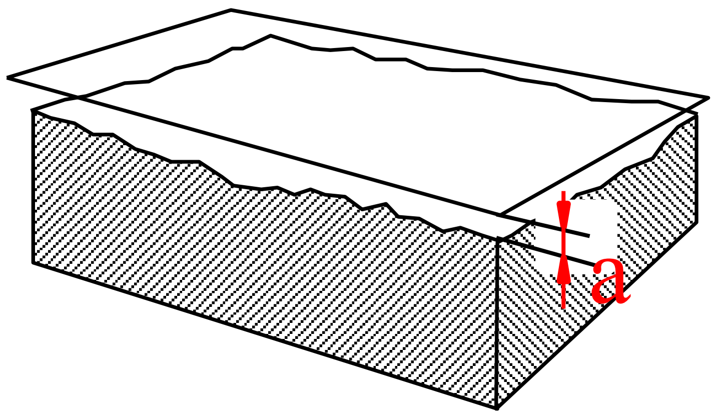
Uniform corrosion

- Uniform corrosion of the whole surface
- Constant rate at constant conditions
- Resistant if less than 0.1mm/year
- Predictable



a = thickness of corroded material

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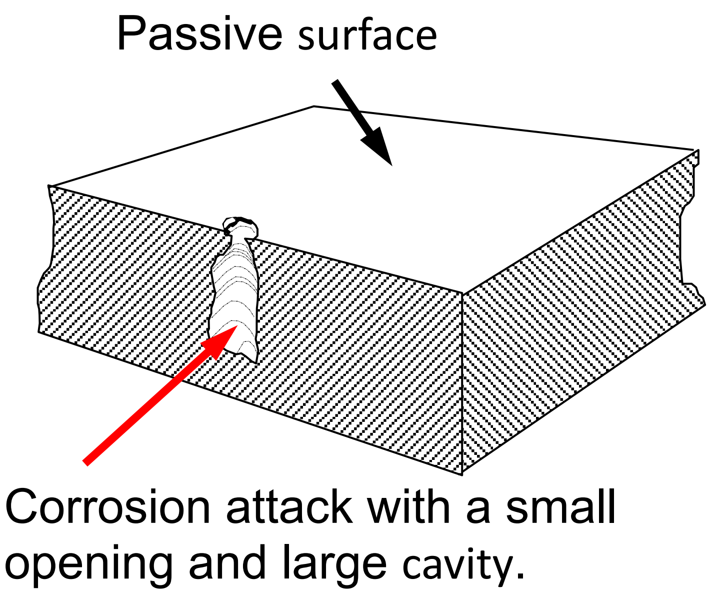
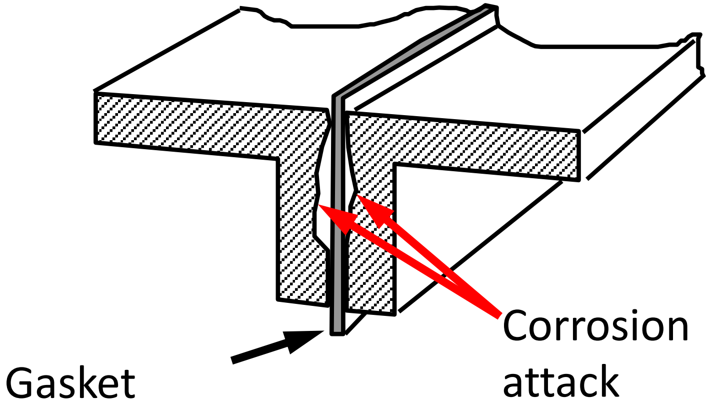
Pitting corrosion



Small but fast growing and deep surface attack
Caused by chlorides (salt)
Improved resistance by addition of : Cr, Mo, N


Pitting on tubes

Crevice corrosion



Occurs in crevices and under deposits
Caused by chlorides on 'occluded' surfaces.
Same corrosion mechanism as in pitting but more aggressive.
Resistance increased by: Cr, Mo and N.

Important alloying elements

Chromium (Cr): Increasing content increases corrosion resistance
Promotes a ferritic structure

Nickel (Ni): Slows the corrosion in acidic environments
Promotes austenitic structure

Molybdenum (Mo): Increases strongly resistance against uniform corrosion
Ferritic promoter and increases risk of precipitates

Nitrogen (N): Very strong austenite former
Increases resistance against localized corrosion

Scrubber material selection

Steel Grade	EN	UNS	Cr	Ni	Mo	N	Other	PRE	CPT, °C (ASTM G150)
316L/ 4404	1.4404	S31603	17	10	2			24	20
316L/ 4432	1.4432	S31603	20	10,5	2,5			25	26
904L	**1.4539**	**N08904**	**20**	**24**	**4,3**			**34**	**62**
254SMO	**1.4547**	**S31254**	**20**	**18**	**6,1**	**0,2**	**< 0,5 Cu**	**43**	**86**
AL6XN	1.4529	N08926	20,5	24,5	6,3	0,2	0,2 Cu	45	>90
4565	1.4565	S34565	24	17	4,5	0,45	5,5 Mn	46	>90
654SMO	1.4552	S32654	24	22	7,3	0,5	3,5 Mn Cu	56	>90
22 Cr - 32205	**1.4462**	**S32205**	**22**	**5,5**	**3**	**0,17**		**35**	**51**
25Cr - 32750	**1.4410**	**S32750**	**25**	**7**	**4**	**0,27**	**Cu**	**43**	**83**
25Cr - 32760	1.4501	S32760	25	7	4	0,25	0,75 W Cu	42	83
Alloy 31	**1.4562**	**N08031**	**27**	**31**	**6,5**	**0,2**	**1,3 Cu**	**52**	**>90**
Alloy 59	**2.4605**	**N06059**	**21**	**59**	**16**			**74**	**>90**
Alloy 625	2.4856	N06625	22	62	8,5		3,5 Nb	52	>90
Alloy C - 276	**2.4819**	**N10276**	**16**	**57**	**16**		**4 W**	**75**	**>90**

PREn=Cr+3,3Mo+16N   PREw=Cr+3,3(Mo+0,5W)+16N

Scrubber material selection

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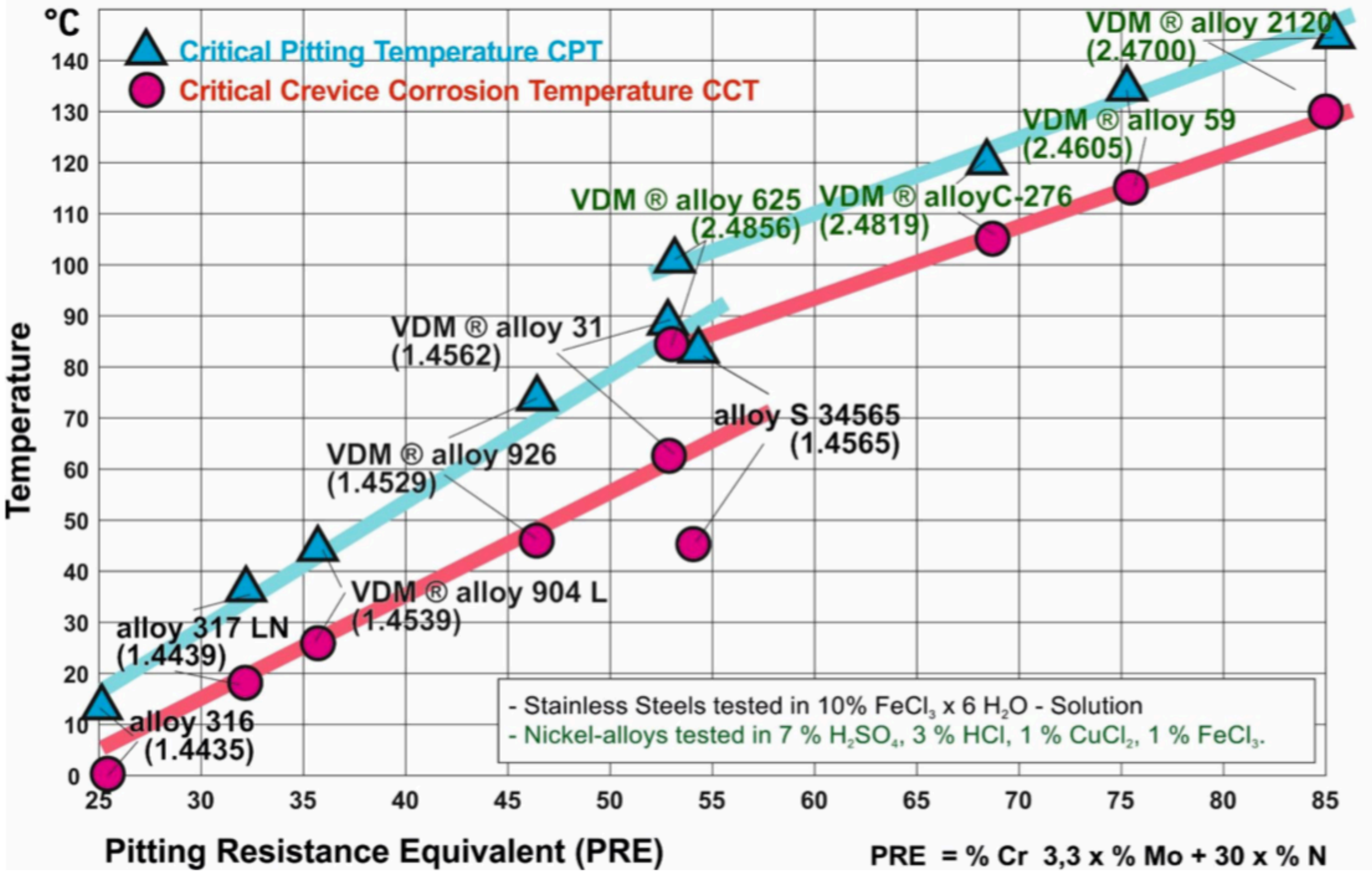
Alloy 59	**2.4605**	**N06059**	**21**	**59**	**16**			**74**	**>90**

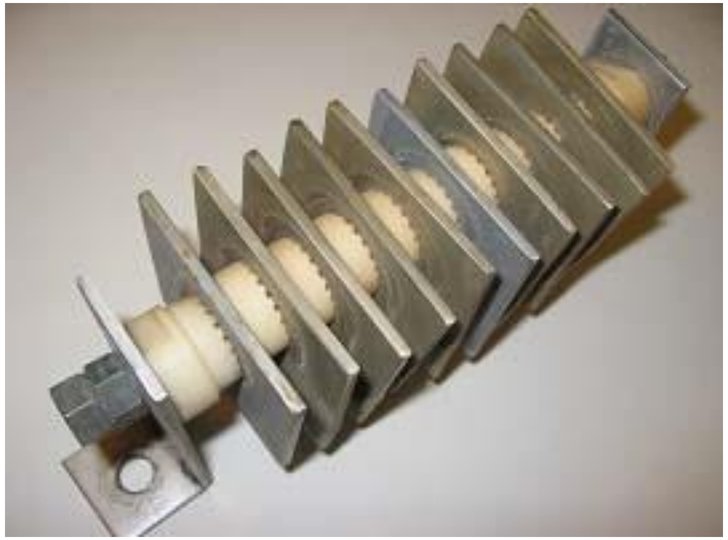
PREn=Cr+3,3Mo+16N   PREw=Cr+3,3(Mo+0,5W)+16N

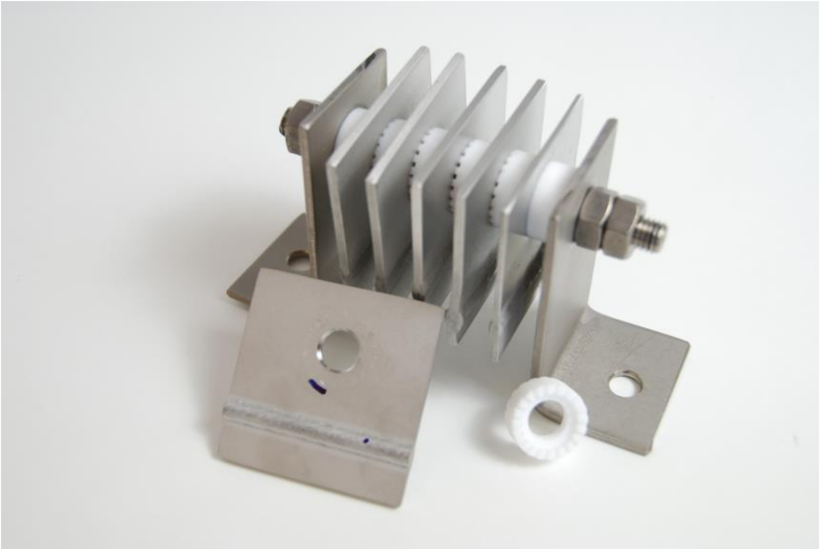
Comparison of Critical Crevice Corrosion Temperature (CCT) and Critical Pitting Temperature (CPT)



Material Concepts for Ship Based SOx Scrubbers, V. Wahl, Achema 2018

Field testing of materials





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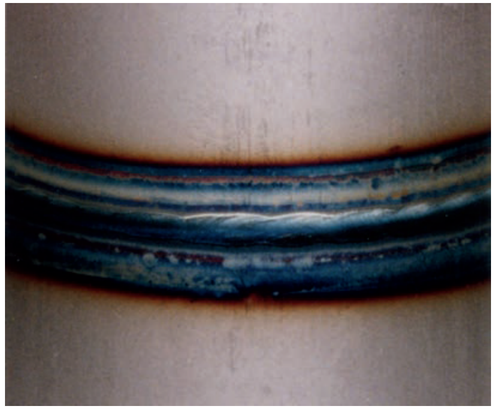
Non optimal conditions

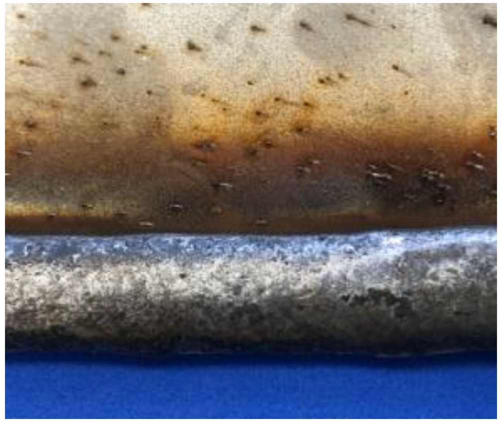
Production issues

Rolled

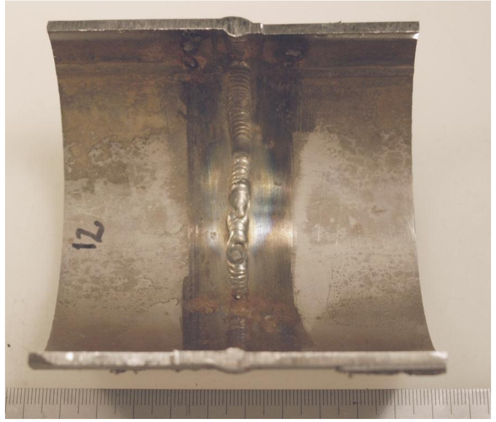
Welding oxides



Spatter



Harsh grinding



Challenges due to:

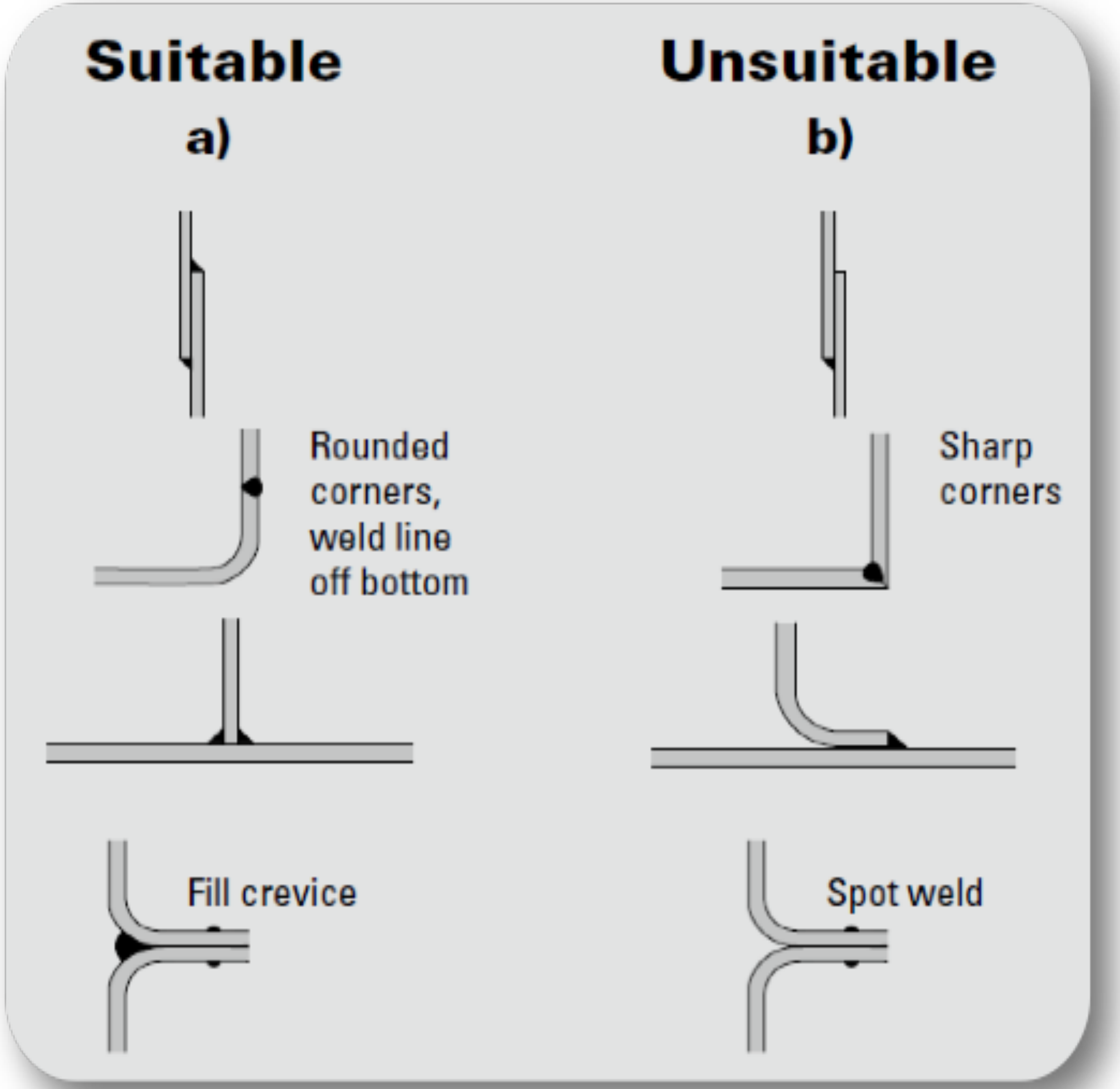
Special stainless steel means tougher demands - mistakes during fabrication are less forgiving and more expensive.

The excellent properties of the base material must be joined with excellent welds.

An improper/incorrect welding procedure is the number 1 cause of failure among failure cases.

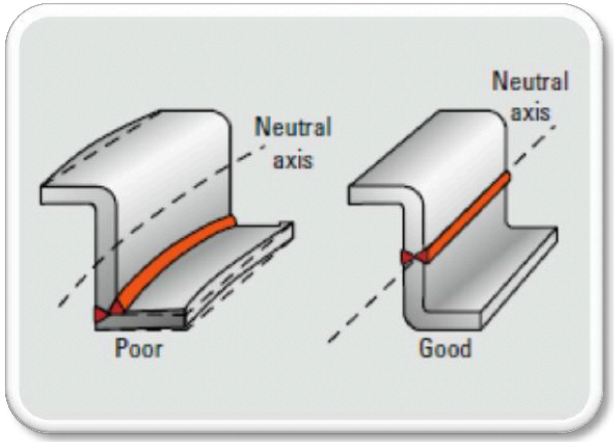
Welding related problems often appear during use of the finished product, corrosion, fatigue, etc.

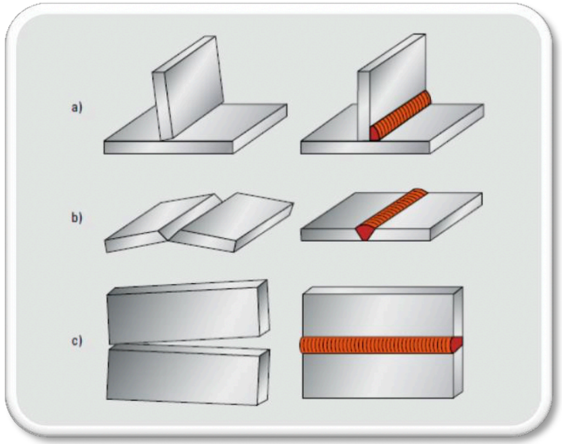
Corrosion issues due to design:

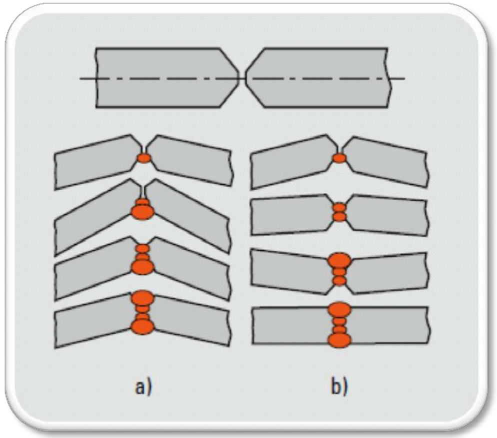


Design to avoid deformation:

- Weld in the neutral axis
- Joint design important, not only for deformations but also corrosion
- Reduce volume of weld metal







Welding :

Identification of parent metal

I C max: CE max: PCM max: II C max: CE max: PCM max:

	Name/Grade	Standard	Group	Delivery cond.	Thickness range [mm]	Diameter range [mm]
I	Duplex		10.1		1,50 – 30,00	–
II	275-500 / 316		1/8		1,50 – 100,0	–

Identification of filler metal

Index	Trade name	Classification	Group	Filler handling
1	Cromacore DW 309MoLP	AWS A5.22: E309LMoT1-4/-1		P0073
2				
3				

Welding Parameters

Equipment:

Pass no.	Index	Dia. [mm]	Welding process	Wire feed speed [m/min]	Current [A]	Volt [V]	Current / Polarity	Welding speed [mm/min]	Run Out Length [mm]	Gas [l/min]	Heat input [kJ/mm]
1-n	1	1,20	136	5,00-7,00	160 – 210	23 -25	DC+	170 – 250			1,0 – 1,8
1-n	1	1,20	136	6,50-8,00	200 – 240	24 -26	DC+	250 – 550			0,6 – 1,4
t<5:				–	–	–		–			–
1-n	1	1,20	136	4,00-6,50	140 – 200	22 -24	DC+	170 – 250			0,7 – 1,7
1-n	1	1,20	136	5,50-7,50	180 – 220	23 -25	DC+	250 – 600			0,5 – 1,2
				–	–	–		–			–
				–	–	–		–			–
				–	–	–		–			–
				–	–	–		–			–

Heat treatment

Method: Heat.torch/ Varmebend

Preheat min: 5 °C Interpass temp. max: 150 °C Heat treatment proc.: Temp. control: Temperature crayon

PWHT min: °C max.: °C Soaking: min/mm Heating rate: °C/h Cooling rate: °C/h

Remarks:
Root opening / Rotåpning: 0-6 mm.
Root face / Rotkantmål: 0-4 mm.
Groove angle / Fugevinkel: 35-65°.
Parent metal / grunnmateriale :
Cover all combinations of group 1, 2, 8 and 10.1
Dekker alle kombinasjoner av gruppe 1, 2, 8 og 10.1

Additional info enclosed (Yes/No):

Date/Signature:
2012-04-19 TOB
Terje [illegible] Bruket
Production Technology Dept.

Approved
2012-04-19 TOB
Terje [illegible] Bruket

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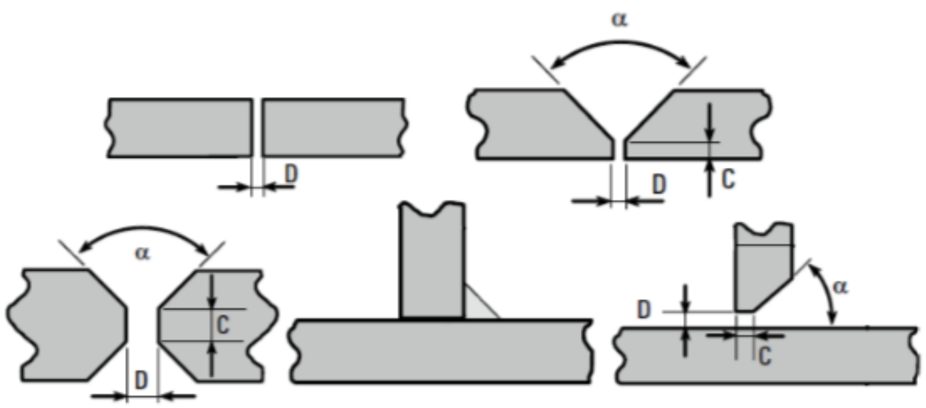
Welding of high alloyed materials

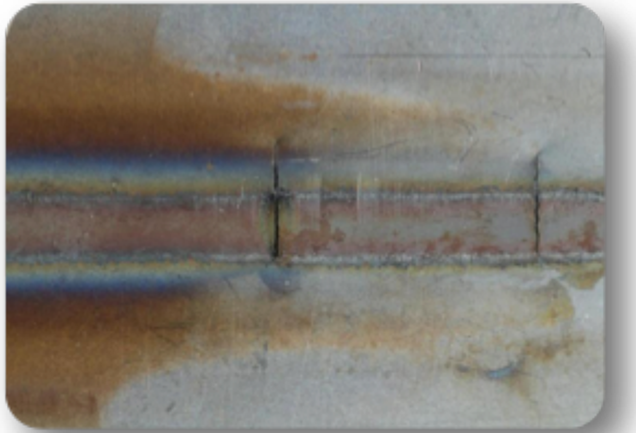


Generally in special stainless steel, e.g. 254SMO, duplexes and Ni- alloys

- Increased joint angle, +10 => 60 -70 , helps penetration
- Shorter root land “nose”, C
- Increased root gap, D, enables filler to reach the root

•Before welding; remove oil, paint, oxides etc. at least 50 mm from the edges

Visible issues due to weld defects:



Defects might facilitate the initiation of corrosion

The corrosion occurs as localized corrosion

Weld defects might affect the corrosion properties by:

- Formation of crevices – undercut, ignition scars
- Destroy the passive layer – slag inclusions, pores
- Introduce contaminants – Low Melting Embrittlement

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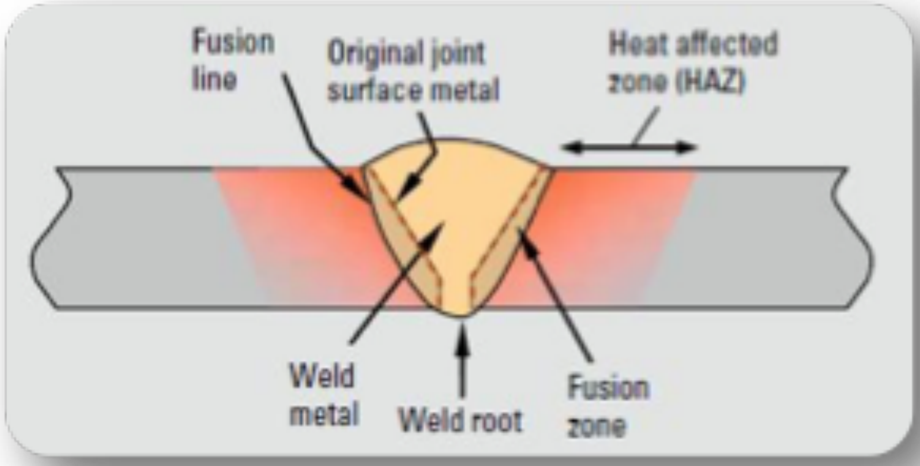
Non visible issues due to heat input:

Level of heat affect on the welded component is dependent on welding parameters

High amount of heat input results in higher level of deformations, avoid to many beads

High degree of clamping results in smaller deformations

Thinner materials are more sensitive to deformations and buckling



General duplex welding guidelines

Preheating: Only drying

Filler metal

Always use filler metal.
Filler metal usually over-alloyed in Ni.

Heat input (control of ferrite-austenite balance)

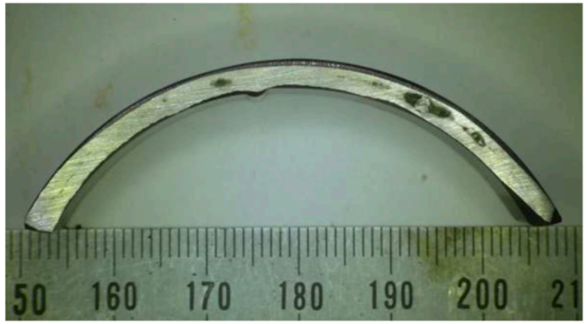
22Cr, UNS S32205: 0.5-3.0 kJ/mm
25Cr, UNS S32750: 0.5-1.5 kJ/mm

Shielding gas:

Shielding gas: Ar (+ He,H_2,N_2)
Purging gas: Ar (+ N_2)

Interpass temperature: 22Cr : T < 150°C , 25Cr : T < 100°C
Post-weld heat treatment: No

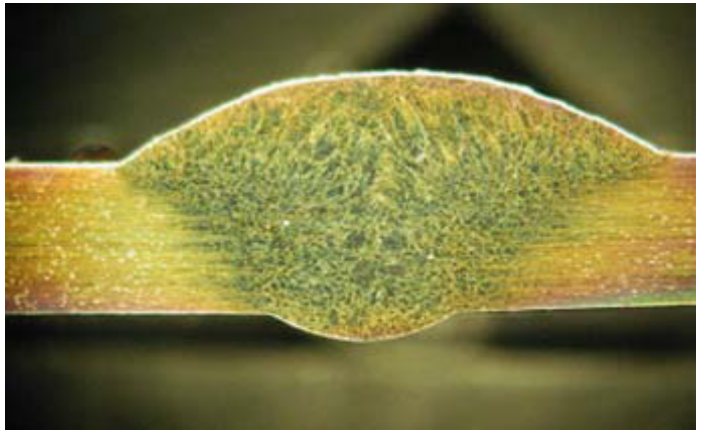
Corrosion test ASTM G48:11 Method A



Corrosion test ASTM G48:11 Method A

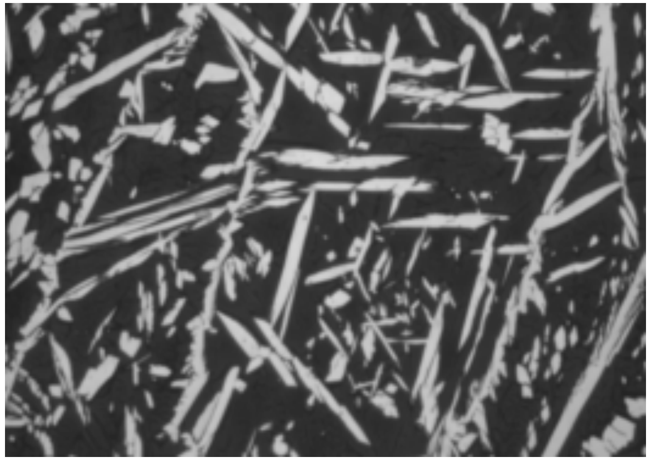
Corrosion issues:

Duplex grades and ferrite content in weld metal



- The ferrite content can vary between
    - 30% - 65% in the weld metal
    - 50% - 95% in the HAZ

Result: great variation of corrosion resistance



- Fast cooling → higher ferrite level
- Slow cooling → risk of detrimental sigma phase

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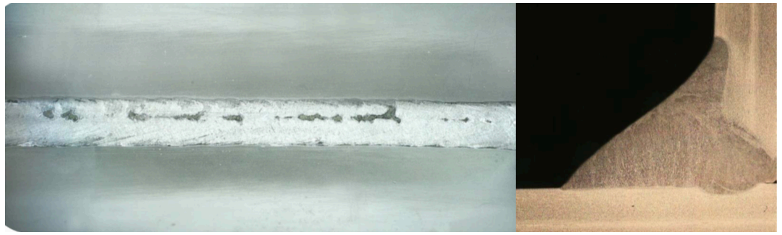
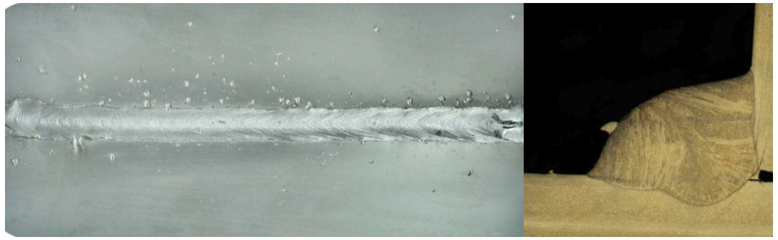
Challenges due to welding processes:

MIG spray arc – embedded surface slag



MIG short arc – embedded surface slag, low spatter

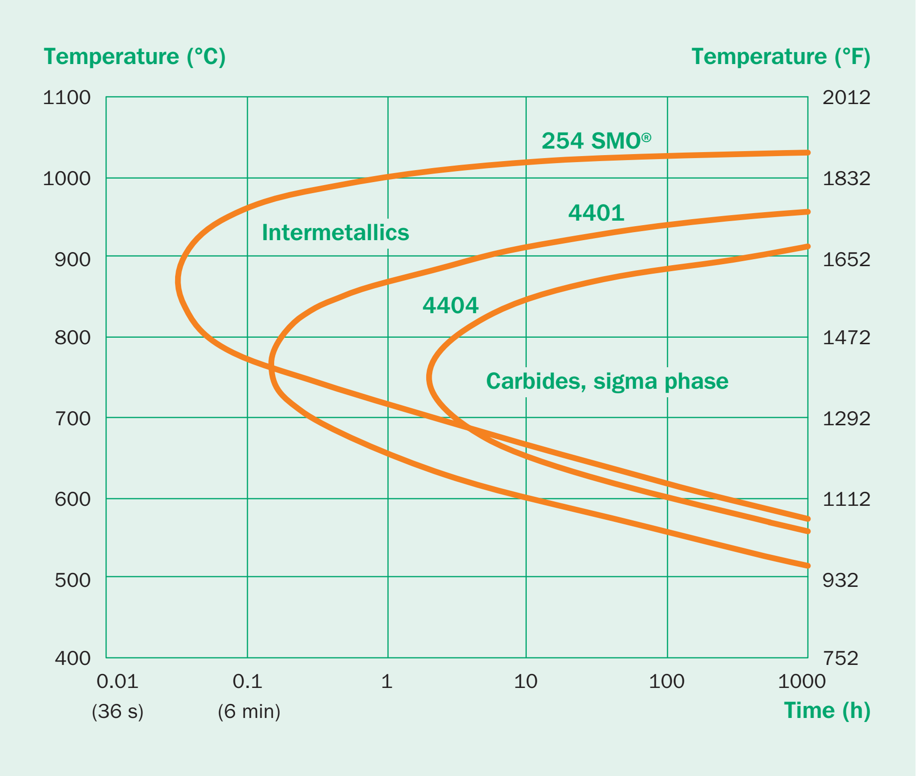
MAG spray arc – convex profile, some spatter

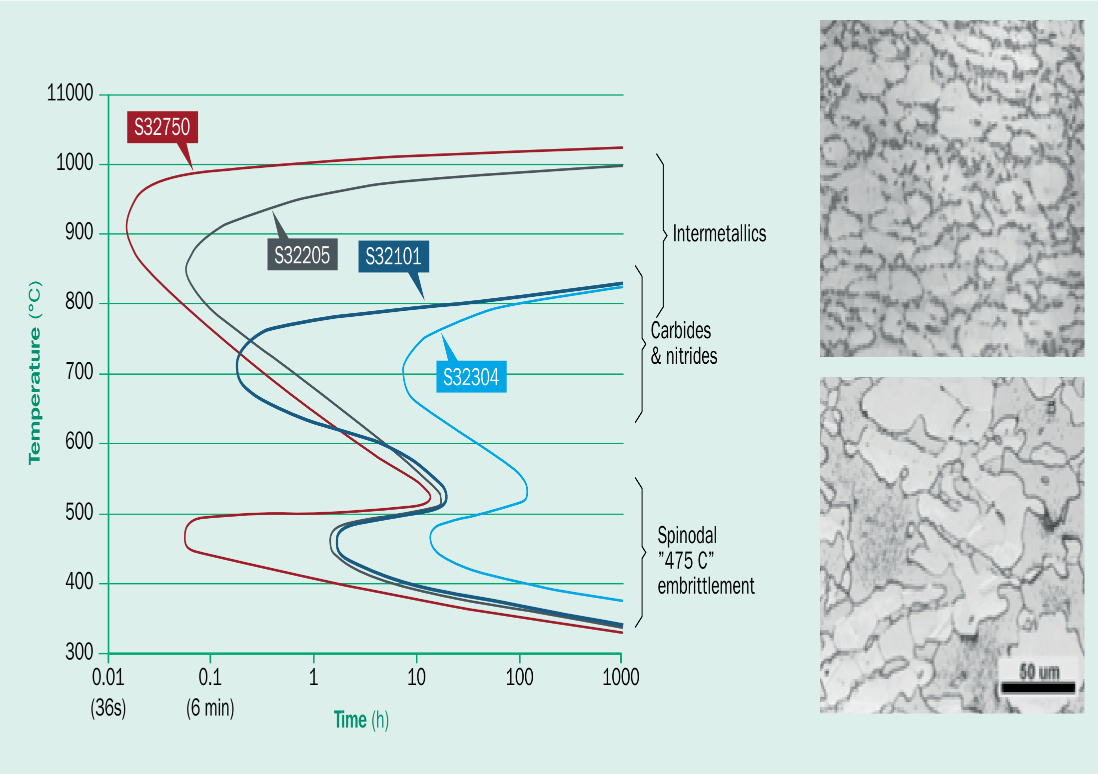


Solution: Pulsed arc welding and a three component gas, for example Ar + 30% He + 2-3% CO_2

Corrosion issues due to:

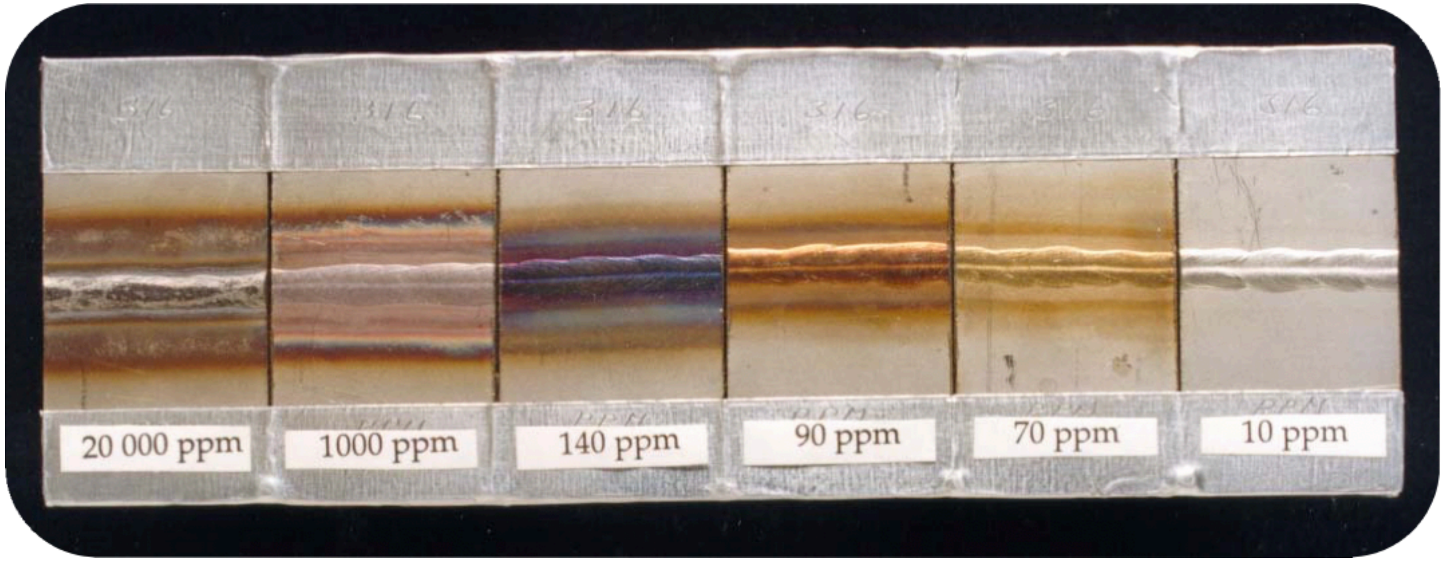
- Welding conditions
  - 22Cr / 25Cr duplex, 6Mo, various nickel alloys
    - Correct welding heat input, interpass temperature, gas protection…





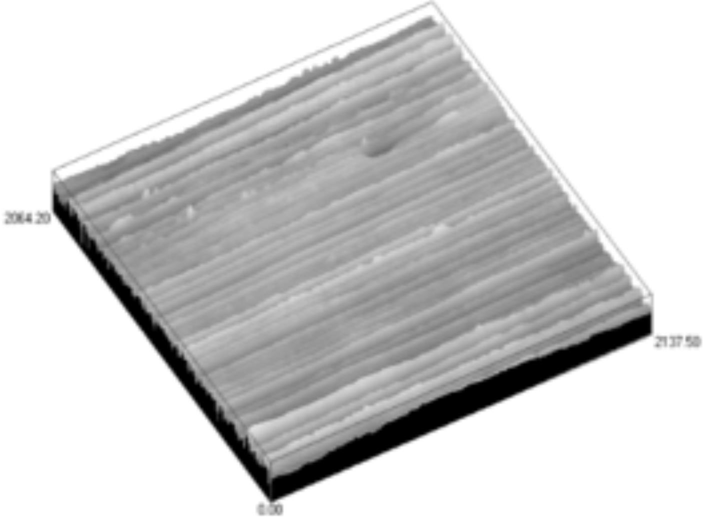
Challenges when welding - oxides

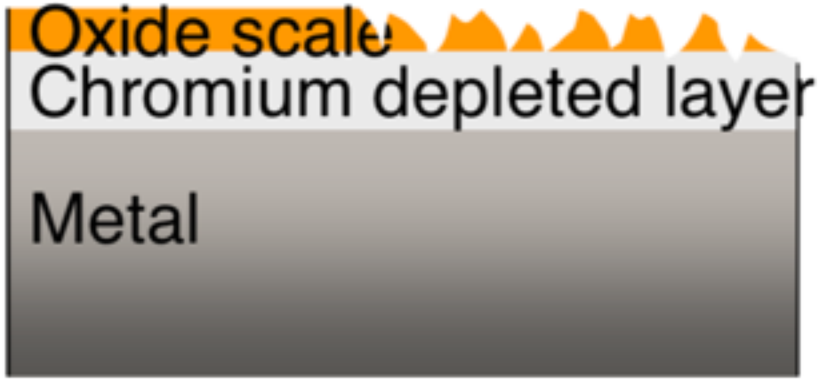
- Weld oxide decreases corrosion resistance
- Sufficient/appropriate shielding gas protection on the root side
- Post weld cleaning often needed to restore corrosion resistance
- Oxides of high nickel alloys and heat tint in the area around welds adhere more strongly than on stainless steels.

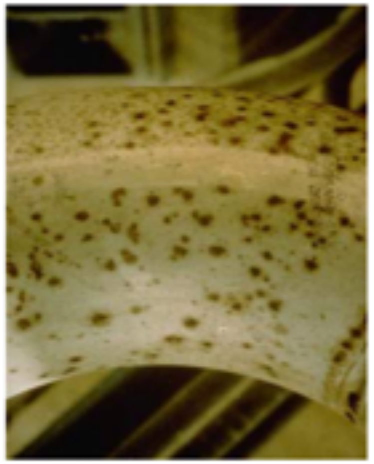


Grinding and polishing

- Removes slag, oxides, chromium depleted layers and geometrical defects
- Smoothness depends on abrasive material and performance
- Coarse grinding causes decreased corrosion resistance
- Use only iron-free abrasive materials
- Grinding spatter gives bad appearance and decreases the corrosion resistance

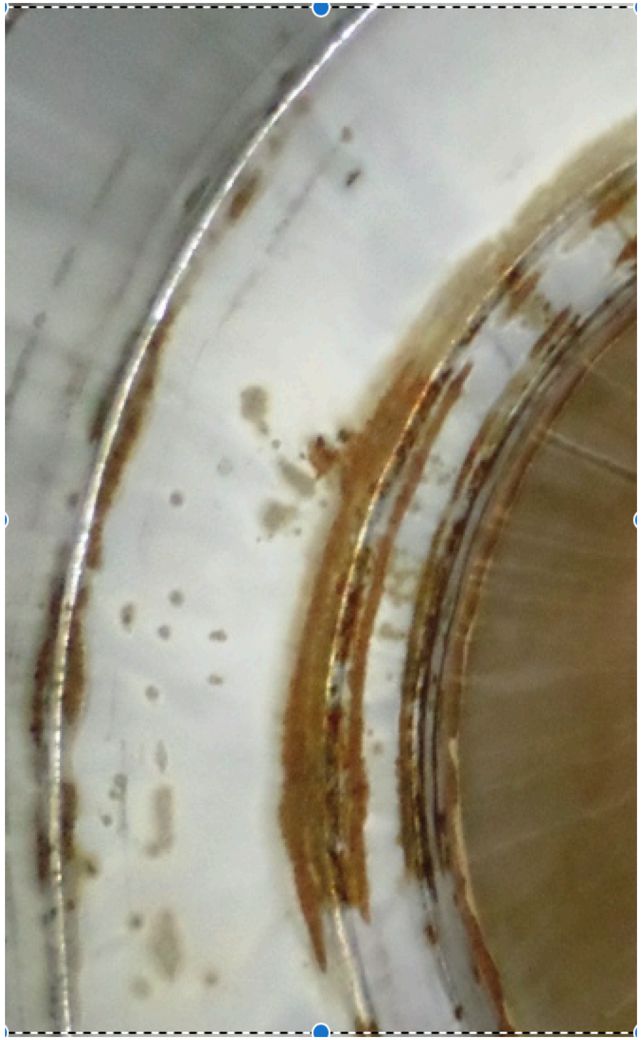






Grinding spatter

Lack of proper surface treatment/ protection



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Surface issues

Welding

Bending

Surface issues

Scratching

Polishing

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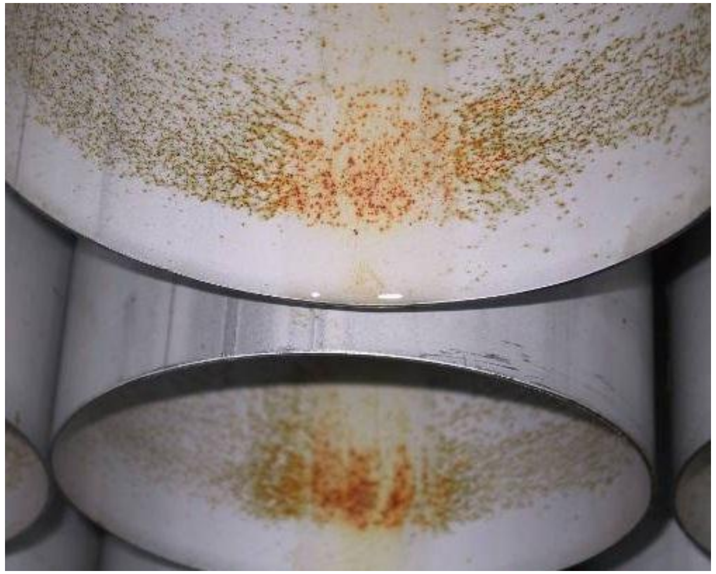
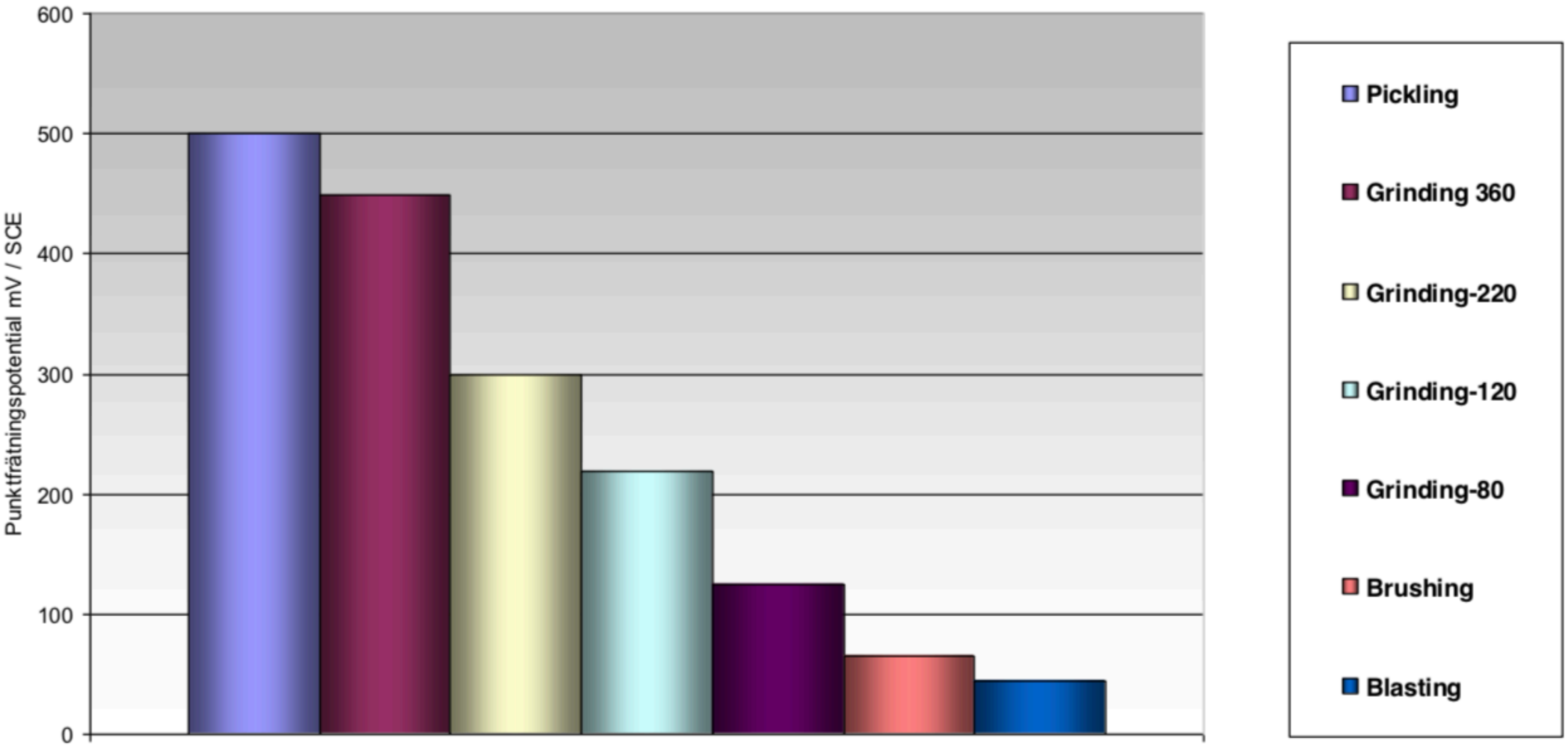
Surface issues



The free iron particles must be removed immediately or else will they rust quickly and break the self healing ”passive film” on the stainless steel surface resulting in pitting corrosion.

Corrosion resistance



Quality acheievement

- Pre production: WPS/ WPQR, with adequate requirements
- Production: Control/ verification of welding parameters.
- QC system of fabricator shall be reviewed by metallurgist/ welding engineer.
- Separate carbon steel and stainless steel in the workshop.
- Ferrite verification of duplex production welds with Ferritescope.
- Control of NDT and pickling process.

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