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# **Canadian Welding Symposium**

## **Stainless Steel Welding**

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## **Technical Support**

- Website- [www.steel.sandvik.com/us](http://www.steel.sandvik.com/us)
- Welding Hotline- 800-781-9449
- Technical Papers
- Industry Conferences
- End User Contact
- Engineering Company Contact
- Technical Seminars

## **Stainless Steel Welding Metallurgy**

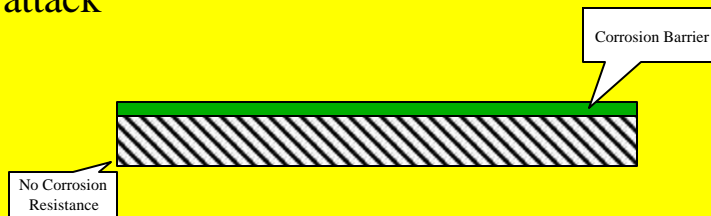
- What are Stainless Steels
- Phases
- Corrosion
- Categories & Weldability
- General Welding Recommendations
- Common Problems and Causes

## **Stainless Steel Welding Metallurgy**

- What are Stainless Steels
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## What Are Stainless Steels?

- Iron based steel with at least 12% Chrome
- Chrome Oxide Layer protects surface from attack



## What Are Stainless Steels?

- Alloying elements affect
  - Corrosion resistance
  - Structure
  - Welding properties

## Major Groups

Group	Chrome	Nickel	Moly
<b>Austenitic</b> EG: 308L	12-27	7-25	0-5
<b>Ferritic</b> EG: 409Cb	12-30(C<.1)	-	-
<b>Martensitic</b> EG: 410	12-18(C .15-.30)	-	-
<b>Duplex</b> EG: 2209	18-25	4-9	0-3
<b>Specialty</b> Superaustenitics EG: 383	> 20	Various	Various

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## **Phases of Stainless Steel**

- **Austenite**
  - **Non-Magnetic**
  - **Ductile**
  - **Strong**
  - **High Toughness at Low Temperature**

## **Phases of Stainless Steel**

- **Martensite**
  - **Magnetic**
  - **Hard**
  - **Brittle**

## **Phases of Stainless Steel**

- **Ferrite**
  - **Magnetic**
  - **Dissolves Impurities**
  - **Transforms to Sigma Phase 1020-1650°F**

## **Role of Ferrite in Austenite (300-Series)**

- |                                    |                                     |
|------------------------------------|-------------------------------------|
| • <b>Positive</b>                  | • <b>Negative</b>                   |
| – Prevents Hot Cracks              | – Selectively Attacked              |
| – Dissolves Phosphorous and Sulfur | – Transforms to Brittle Sigma Phase |

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## Corrosion

- **General Corrosion**
  - Desirable
  - Uniform Loss of Material
  - Predictable

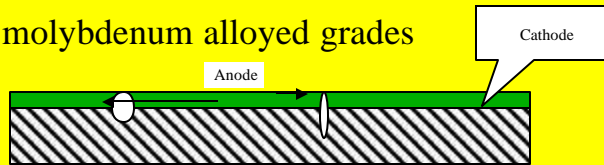




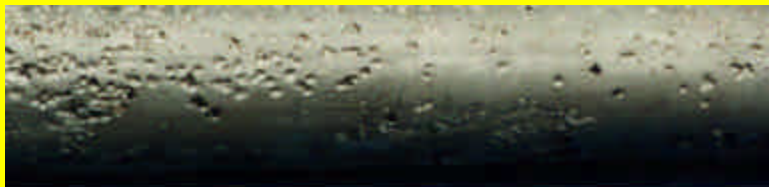
# Corrosion

- **Pitting**

- Caused by Oxides films, impurities at surface, inclusions( Be aware of Iron contamination)
- Proceeds quickly after initiated - unpredictable
- Use molybdenum alloyed grades



## Pitting Corrosion of an Austenitic Stainless Steel Tube



## Pitting Corrosion Micrograph of an Austenitic Stainless Steel Tube



## Pre-Numbers

### Alloy Comparisons

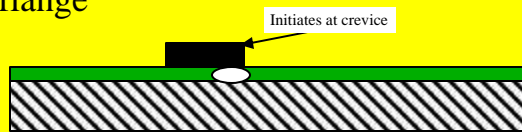
	Cr	Mo	N	PRE
<b>304L</b>	18.4			18.4
<b>316L</b>	17	2.2		24.3
<b>2304</b>	23		0.1	24.6
<b>2205</b>	22	3	.14	34.1
<b>2507</b>	25	4	.25	42.2

$$\text{PRE} = \text{Cr} + 3.3\text{xMo} + 16\text{xN}$$

# Corrosion

- **Crevice Corrosion**

- Same Mechanism as Pitting
- Once initiated progresses quickly
- Unsealed tube-tubesheet welds, unwelded pipe and flange

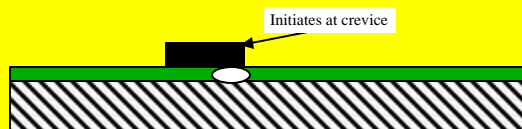


# Corrosion

- **Crevice Corrosion**

- **Avoid in Design Stage**

- Molybdenum alloyed grades will reduce
- Be aware of residual slag



## Corrosion

- **Stress Corrosion Cracking Prevention**

- Ferritic Grades- Poor Toughness
- High Nickel Grades- Expensive
- Duplex
  - Good Toughness
  - Economical Alternative



## Corrosion

- **Carbide Precipitation & Intergranular Corrosion**

- Depletes Chrome
- Reduced corrosion resistance
- Keep carbon below .05%
- Occurs between 1000-1600°F
- Heat Affected Zone

## **Corrosion**

- **Carbide Precipitation & Intergranular Corrosion**
- **Three ways to prevent**
  - Solution anneal
  - Stabilize carbon with Niobium
  - Use Low Carbon Stainless Steel

## **Corrosion**

- **Galvanic Corrosion**
- **Occurs when two grades are joined together**
  - Low alloy to stainless
  - Nickel to stainless
  - Different grades of stainless
- **Avoid in design stage**

# Stainless Steel Welding Metallurgy

- What are Stainless Steels
- Phases
- Corrosion
- Categories & Weldability
- General Welding Recommendations
- Common Problems and Causes

## Major Group Weldability

Group	Ferrite	Weldability	Comments
<b>Austenitic</b> EG: 308L	3-15	Excellent	User Friendly
<b>Ferritic</b> EG: 409Cb	100	Good	Loss of Toughness
<b>Martensitic</b> EG: 410	0	Difficult	Crack Sensitive
<b>Duplex</b> EG: 2209	50	Caution	Follow Welding Recommendations
<b>Specialty</b> Superaustenitics EG: 383	0	Caution	Crack Sensitive

## **Stainless Steel Welding Metallurgy**

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## **Austenitic Stainless Steels Weldability (300 Series)**

- **Excellent Weldability**
- **No Preheat**
- **No Postweld Heat Treat**
- **50% greater Thermal Expansion over Carbon Steel**
- **Use Low Heat Input**
  - (amps x volts x 60)/Travel (in/min)
- **300 Deg Interpass Temp**

## **Ferritic Stainless Steels**

### **Weldability (400 Series)**

- **Not as weldable as Austenitic**
- **Preheat on thick sections**
- **Grain Growth** (Loss of toughness)
- **Carbide Precipitation**
- **Use matching filler metal**
- **Can often use 300 Series or Nickel to weld**

## **Martensitic Stainless Steels**

### **Weldability (400 Series)**

- **Hardenable**
- **Preheat**
- **Stress Relief**
- **Slow Cool**
- **Keep Stresses Low**
- **Can often use 300 Series or Nickel to weld**



## **Duplex Stainless Steels Weldability (300 Series)**

- **Good Weldability**
- **No Preheat**
- **No Postweld Heat Treatment**
- **Stay within recommended Heat Input**
  - $(\text{amps} \times \text{volts} \times 60) / \text{Travel (in/min)}$
- **Use larger root than 300 Series**
- **Less good flow than 300 Series**

## **Superaustenitic Stainless Steels Weldability (300 Series)**

- **Somewhat Difficult Weldability**
- **No Preheat**
- **No Postweld Heat Treat**
- **Use Low Heat Input**
  - $(\text{amps} \times \text{volts} \times 60) / \text{Travel (in/min)}$
- **Use Flat to Convex Weldbeads**
- **Interpass Temp 300 Deg F**

## **Stainless Steel Applications**

- **Joining of Similar Base Metals**
- Joining of Stainless Steel to Low or Unalloyed Base Materials
- Joining of Stainless Steel to Nickel Base
- Dissimilar Joining of Stainless Steel
- Welding Hints
- Common Problems and Causes

## **Joining of Similar SS**

- Use filler metal of matching composition
  - e.g.: weld 304L with 308L
- Filler Metal often different balance of alloy to prevent cracking
- Move up in alloy content if history shows preferential attack of filler metal
  - Be aware of galvanic corrosion

## Families of Alloys

### 308

<b>308</b>	.08 Max Carbon ( 304 Base )
<b>308H</b>	.04-.08 Carbon ( High Temperature )
<b>308L</b>	.04 Max Carbon ( 304L or 304 Base )
<b>308LSi</b>	High Silicon ( Improved spray transfer and weld metal flow )
<b>308/308L</b>	Dual Marked where requirements for both classifications are met

## Families of Alloys

### 316

<b>316</b>	.08 Max Carbon ( 316 Base )
<b>316H</b>	.04-.08 Carbon ( High Temperature )
<b>316L</b>	.04 Max Carbon ( 316L or 316 Base )
<b>316LSi</b>	High Silicon ( Improved spray transfer and weld metal flow )
<b>316/316L</b>	Dual Marked where requirements for both classifications are met

## Joining of Similar SS

<b>2209</b>	Duplex Base Metals 3RE60,2205,2304
<b>307</b>	307 Base Metal (VW)
<b>310</b>	310 Base Metal
<b>317L</b>	317L Base Metal 316L Base Metal for higher corrosion resistance

## Joining of Similar SS

<b>347</b>	321 Base Metal stabilized with Ti 347 Base Metal stabilized with Nb (Cb)
<b>383</b>	San 28 2RK65(904L) for higher corrosion resistance
<b>385</b>	2RK65(904L)

## Stainless Steel Applications

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## Families of Alloys 309

<b>309</b>	.08 Max Carbon ( 304 to Low Alloy)
<b>309L</b>	.04 Max Carbon ( 304,304L to Low Alloy )
<b>309LHF</b>	High Ferrite ( Problem solver for cracking)
<b>309LSi</b>	High Silicon( Improved spray transfer and weld metal flow )
<b>309LMo</b>	316L weld deposit when overlaying low alloy steel
<b>309LCb</b>	347 weld deposit when overlaying low alloy steel

# Dissimilar Joining SS to Low Alloy

~~308~~

Do not use, under alloyed, forms brittle welds due to formation of Martensite. Risk of cracking.

**309 Type**

Overalloyed to account for dilution.

**312**

Overalloyed to account for dilution. Avoid using for high temperature applications over 750°F

**310**

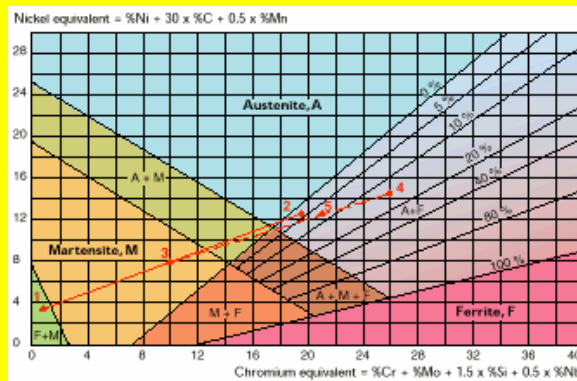
Overalloyed to account for dilution. Good for high temperature over 750°F

~~Low Alloy~~

Do not use, forms brittle welds. High risk of cracking

**Nickel**

Excellent for High Temperature over 750°F



Mild steel (AISI 1010 – point 1) is to be welded to austenitic stainless steel (AISI 304 – point 2). We expect in this case that the two parent metals to contribute equal amounts of material to the weld metal. If welding is done without filler metal, the distance – 2 is divided in the middle at 3, which represents the 50/50 composition of the weld metal. The structure at 3 is martensitic. As a rule this cannot be allowed, because it involves a serious risk of cracking.

The problem can be solved by using an overalloyed filler metal such as 24.13.LHF (point 4). The composition of the weld metal will then be somewhere along the line 3 – 4. Its exact position on the line will depend on the degree of dilution, i.e. the proportion of fused parent metal in the weld metal, generally 20 – 40%.

A suitable austenitic, crack-proof weld-metal structure with approx. 8% ferrite can be obtained at about point 5, which represents a dilution of 30% (the dilution is calculated as the distance between 5 and 4, divided with the distance between 3 and 4, and x 100%.)

## Stainless Steel Applications

- Joining of Similar Base Metals
- Joining of Stainless Steel to Low or Unalloyed Base Materials
- **Joining of Stainless Steel to Nickel Base**
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## Dissimilar Joining SS to Nickel

### Nickel

Always use nickel base filler metals when joining stainless steel to nickel.

### ~~Stainless Steel~~

Do not use, forms crack sensitive welds. High risk of failure.

## **Stainless Steel Applications**

- Joining of Similar Base Metals
- Joining of Stainless Steel to Low or Unalloyed Base Materials
- Joining of Stainless Steel to Nickel Base
- **Dissimilar Joining of Stainless Steel**
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## **Dissimilar Joining SS to SS**

- Dissimilar Joining Chart in Catalog
- Generally use the lower alloyed of the two base metals(e.g. use 308 to join 304 to 316)



## **Stainless Steel Applications**

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## **Welding Hints**

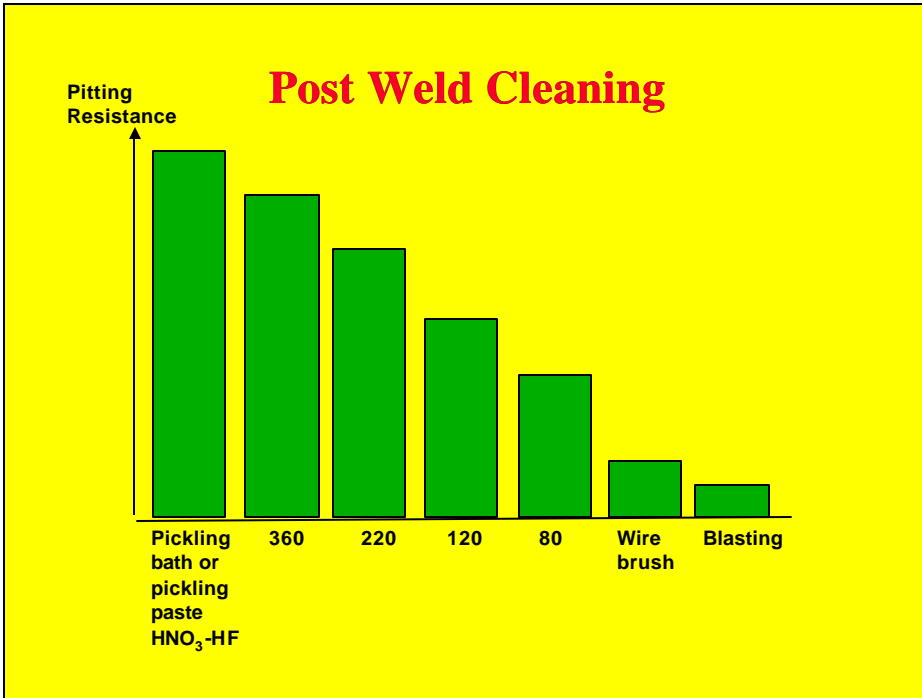
- **Clean Joint Preps**
  - Finish Grind Carbon Arc Preps to avoid Carbon Pickup
  - Remove all contamination
  - Beware of Nitrogen in Plasma Cutting
- **Avoid Narrow Joint Preps**
  - Can cause lack of fusion
- **Use Certified Materials**
  - some Stainless Steels are not weldable (Machinable Grades)

## **Welding Hints**

- **Post Weld Cleaning**
  - Optimizes corrosion resistance by ensuring a good Chrome Oxide film
  - Remove all slag and spatter which form crevices
- **Use Stainless Steels Tools**
  - Avoid contamination with Carbon Steel
- **Use uncontaminated media**
- **Remove Heat Tint**

## **Welding Hints**

- **Post Weld Cleaning Methods**
  - Pickling, Grinding, Blasting, Brushing, Polishing
- **The Finer the Surface, the better the Corrosion Resistance**



## Welding Hints

- Guard Against Moisture
  - Condensation
  - Proper Storage
- Do not mix Carbon Steel Fabrication with SS
- Avoid Contamination
  - Protective Paper
  - Cutting Oils
  - Paint, Penciling, Anti-Spatter

## **Welding Hints**

- Use short arc length
  - Prevents loss of Chrome and Nitrogen pick-up
- Back fill craters
  - Cracks do not get better

## **Stainless Steel Applications**

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- **Common Problems and Causes**

## Common Problems and Causes Cracking

- Observe Type of Crack:
  - Center of Weld - dilution problem
    - Use higher alloy
    - Change technique to avoid concave beads
    - Lower Heat Input
  - Across the Weld or Random - too high stresses
    - More frequent tacks
    - Step welding
    - Too much distortion from too high heat input
      - $(\text{Amps} \times \text{Volts} \times 60) / \text{Travel Speed}$

## Common Problems and Causes Cracking

- Observe Type of Crack:
  - Heat Affected Zone - Base metal related
    - Machinable Grade being used?
    - Too High Heat input
    - Carbon Migration during stress relief

## **Common Problems and Causes Rust**

- Lack of Post Weld Cleaning
- Use of Contaminated Cleaning Equipment
- Contaminated Fixtures or Handling Equipment
- Plasma Cutting with Air or Nitrogen

## **Common Problems and Causes Undercut**

- Wrong Welding Speed
- Grounds
- Arc Blow
- Low Sulfur Base Metal- use HiSil Consumables

## **Common Problems and Causes**

- **Distortion-** Heat Input , Step Welding
- **Arc Blow-** Grounding, use AC
- **Slag Inclusions**
  - Welding over Slag
  - Use gravity to advantage, not disadvantage
- **Poor Wetting**
  - Weld Metal Composition
  - Gas Selection

**Questions?**