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Canadian Welding Symposium

Stainless Steel Welding

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Technical Support

- Website- www.steel.sandvik.com/us
- Welding Hotline- 800-781-9449
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Stainless Steel Welding Metallurgy

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

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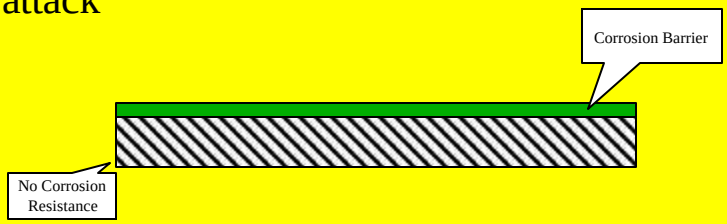
What Are Stainless Steels?

- 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
Austenitic EG: 308L	12-27	7-25	0-5
Ferritic EG: 409Cb	12-30(C<.1)	-	-
Martensitic EG: 410	12-18(C .15-.30)	-	-
Duplex EG: 2209	18-25	4-9	0-3
Specialty 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)

- **Positive**
  - Prevents Hot Cracks
  - Dissolves Phosphorous and Sulfur
- **Negative**
  - Selectively Attacked
  - Transforms to Brittle Sigma Phase

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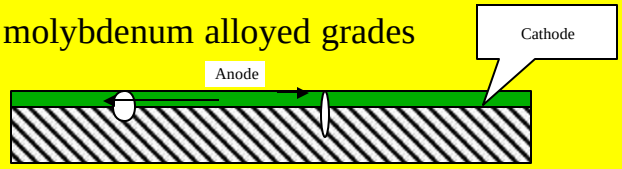
Corrosion

- **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

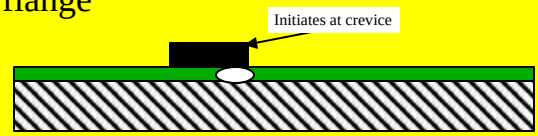
Alloy Comparisons

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

PRE = Cr + 3.3xMo + 16xN

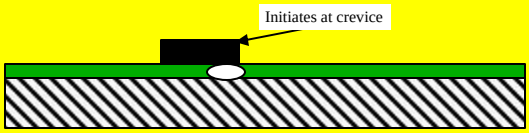
Corrosion

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



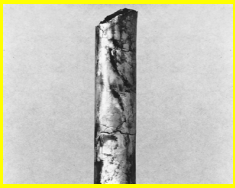
Corrosion

- **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^{o}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**

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Major Group

Weldability

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

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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**
  - (amps x volts x 60)/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**
  - (amps x volts x 60)/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

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

Families of Alloys
316

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

Joining of Similar SS

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

Joining of Similar SS

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

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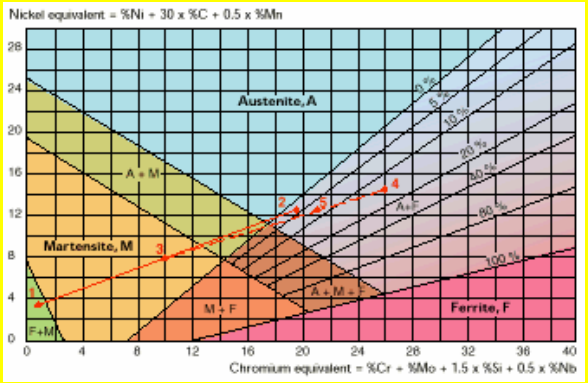
Families of Alloys
309

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

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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.

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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)

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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)

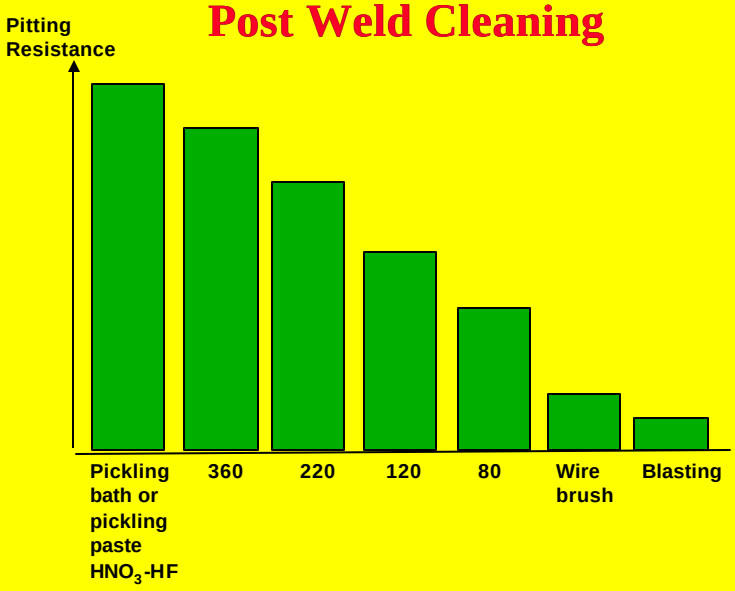
Welding Hints

- 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

Post Weld Cleaning



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

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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
      - (Amps x Volts x 60) / 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?