



# Tech Talk Tech Talk

Welcome to the fifth issue of *Tech Talk*. This newsletter covers a range of topics on various welding products, applications, metallurgy, techniques, and economics. Previous issues are archived at [www.unibraze.com](http://www.unibraze.com). Submit any questions or comments to Leroy Billesberger, at [leroy@unibraze.com](mailto:leroy@unibraze.com) or call 1-877-233-1375.

In this issue, we will look at the filler metals that fall under the AWS A5.4 “Stainless Steel Electrodes for Shielded Metal Arc Welding” (SMAW).

There is so much data available on Stainless Steel that whole books have been written. This newsletter will focus on the most commonly asked questions. If you have other stainless steel questions that haven’t been covered, please send me an email and I will reply as soon as possible.

## What is Stainless Steel?

Stainless steel is essentially a low carbon steel that contains chromium at 10% or more by weight. It is this addition of chromium that gives the steel its unique stainless, corrosion-resisting properties.

The chromium content of the steel allows the formation of a rough, adherent, corrosion-resisting chromium oxide film on the steel surface. If damaged mechanically or chemically, this film is self-healing, providing that oxygen, even in very small amounts, is present. Corrosion resistance and other useful properties of the steel are enhanced by increased chromium content and the addition of other elements such as molybdenum, nickel and nitrogen.

There are more than 60 grades of stainless steel. However, the entire group can be divided into five classes. Each is identified by the alloying elements which affect their microstructure and for which each is named.

## Alloying elements in Stainless Steel:

Most metals are not used in their pure form but have alloying elements added to change their properties. The addition of a second element such as chromium to iron, can significantly alter the corrosion properties. “Stainless Steel” is the general name for a large family of alloys that contain at least 10.5% chromium. At and above this level, an extremely thin surface layer is instantaneously formed, as long as oxygen is present, it will prevent the diffusion of oxygen atoms through this layer and protect the iron in the matrix from rusting. This is called “passivation”. Material in the passive condition is highly corrosion resistant. Several other alloying elements can be added to this chrome-iron matrix to form well over 150 different compositions, each with unique characteristics. This

family of stainless steels can be divided into five (5) categories:

### 1) AUSTENITIC STAINLESS STEELS Fe-Cr-Ni (Mo) alloys:

The carbon content is generally held to a maximum of 0.08% (302, 309 & 310 have slightly higher levels). Chromium is in the range of 16.0 to 28.0%, and nickel between 3.5 & 32.0%. These alloys cannot be hardened by heat treatment and are non-magnetic. They all exhibit excellent corrosion resistance (Molybdenum is added for resistance to chlorides), and have great ductility and toughness.

### 2) FERRITIC STAINLESS STEELS Fe-Cr (Mo) alloys:

The carbon levels here are also low, generally below 0.12% (442, 446 are at 0.20). The chromium content can vary from 10.5 to 30.0%. These grades cannot be hardened by heat treatment, but are magnetic. They have good corrosion resistance, particularly to chloride stress corrosion cracking, but are generally not chosen for toughness.

### 3) MARTENSITIC STAINLESS STEELS Fe-Cr-C (Ni Mo) alloys:

These grades do have a relatively high carbon level compared to the other categories. Carbon can range from 0.15 to 1.20%. Chromium levels between 11.5 & 18.0%. They can be heat-treated to a very high hardness level. They are also magnetic.

### 4) DUPLEX STAINLESS STEELS Fe-Cr-Ni (Mo)-N alloys:

These are a combination of both austenitic and ferritic structures. The carbon levels are very low (below 0.03%). Chromium is between 21.0% & 26.0% with nickel from 3.5 to 8.0%. Duplex stainless steels may also contain molybdenum up to 4.5% and nitrogen 0.05 to 0.30%. These alloys are magnetic and offer increased tensile and yield strength over the other categories.

### 5) PRECIPITATION HARDENING STEELS Fe-Cr-Ni (Mo-Cu-Al-Nb) - N alloys:

Being low carbon (0.09 max.), they have good corrosion resistance and are characterized by ease of fabrication. High-strength can be developed at relatively low temperature (500-



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800C), so distortions are minimized. Chromium is between 12.25% & 18.0%, with nickel 3.0 to 8.5%. Molybdenum is also present in some grades between 2.0 and 2.5%, with additions of aluminum, copper, rare earths and nitrogen.

### Summary of alloying elements in Stainless:

Chromium	Forms a passive film with oxygen that prevents the further diffusion of oxygen into the surface.  Minimum of 10.5% Chromium is required to be considered a stainless steel.
Nickel	Increases ductility and toughness. Increases corrosion resistance to acids. Nickel Addition also creates a non-magnetic structure.
Molybdenum	Increases pitting and crevice corrosion resistance. Increases resistance to chlorides.
Copper	Increases corrosion resistance to sulfuric acid.
Manganese	Substitute for nickel (200 series).
Titanium/Niobium	Ties up carbon and prevents inter-granular corrosion in welded zone of ferritic grades.
Nitrogen	Increases strength and corrosion resistance in austenitic and duplex grades.
Silicon	Improves resistance to high-temperature scaling.
Sulfur	Usually kept low except for "free-machining" grades.
Carbon	Usually kept low. Used in martensitic grades to increase strength and hardness.

### Stainless Alloy Classifications and what they are used for:

#### 200 Series Austenitic – Alloys: 201, 202, 203, 204 & 205

-Chromium-nickel-manganese alloy with high strength in the annealed state. Non-magnetic, not heat treatable and has excellent formability.

-Typical use: washing machine tubs, structural applications.

#### 300 Series Austenitic – Alloys: 301, 302, 303, 304, 305, 308, 309, 310, 314, 316, 317, 321, 330, 347, 384

-Chromium-nickel alloy that can develop high strength by cold working. Non-magnetic, not heat treatable, and has good formability. Additions of molybdenum can increase the corrosion resistance.

-Typical use: Food equipment, chemical equipment, architectural applications

#### 400 Series Ferritic – Alloys: 405, 409, 429, 430, 434, 436, 442, 446

-Straight chromium alloy, magnetic, but not heat treatable.

-Typical use: Automotive trim, cooking utensils

#### 400 Series Martensitic – Alloys: 403, 410, 414, 416, 420, 422, 431, 440

-Straight chromium alloy, magnetic, but can be hardened by heat treatment.

-Typical use: Fasteners, pump shafts, turbine blades

#### Precipitation Hardening – Alloys: 13-8, 15-5, 15-7, 17-4, 17-7

-Chromium-nickel, martensitic or austenitic. These alloys develop strength by precipitation hardening reaction due to heat treatment.

-Typical use: valves, gears, petro-chemical equipment

#### Duplex – Alloys: 329, 2205, 2304, 2507, 3RE60

-Chromium-nickel-molybdenum. More resistant to stress corrosion cracking than austenitic, yet tougher than fully ferritic alloys.

-Typical use: pipelines, pressure shafting

### Understanding the AWS designation on Stainless Electrodes:

In the following example you will see the relationship of the AWS specification to the electrode E316L-16;

E= Electrode

316= The grade of stainless steel

L= Low carbon content on the electrode

16= type of coating on the electrode

There can be other designators to the electrodes. Some examples are the "Mo" after the L in E309LMO-16. In this designation, the Mo stands for Molybdenum that has been added to the electrode. Another is E410NiMo-16. In this one there has been the addition of Nickel (Ni) and Molybdenum (Mo) to the E410 electrode.

#### Types of coatings available:

Factors such as the coating type and core wire analysis affect the corrosion resistance and mechanical properties of the weld metals. There are various types of coatings but the three most



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commonly used are the -15, -16, and -17 coatings. Each coating type has its own area of application.

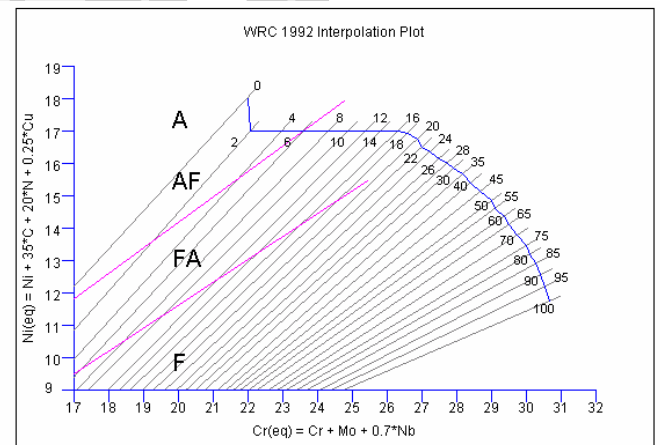
**The -15 coating** gives the cleanest weld metal, which is usually the lowest oxygen and inclusions, and are more resistant to moisture and porosity. The weld metal tends to be tougher, more ductile and crack resistant, and have higher corrosion resistance. While having good all-position characteristics, it does have the tendency to spatter more and slag is harder to clean than the -16 or -17 electrodes thus it is not high on the fabricators “welder appeal” list. It is normally usable only with direct current and should be the choice of the most demanding applications.

**The -16 coating** is a general purpose electrode. The major component is rutile, also known as Titania, along with limestone, which is why the coating type is sometimes referred to as basic-rutile. These AC-DC electrodes are the most popular type, and have the following characteristics: Excellent starting properties that are obtained with all types of AC welding equipment. The arc is stable and smooth with fine spray weld metal transfer. The bead is uniform, flat or slightly concave with straight-line feathered edges. Penetration is complete and the weld metal is free from porosity. Slag is easily and completely removed, which means less cleaning, grinding and polishing time. The -16 electrodes give good out-of-position characteristics. The mechanical properties are similar to the weld metal from the -15 coated electrodes except they tend to be stronger with good ductility.

**The -17 coatings** are also titania based, in addition to containing a high proportion of silicates and other acid components. These electrodes are very easy to use on AC as well as DC. The -17 coated electrodes were developed for application where the weld bead was to be smooth, blending into the base metal to minimize grinding where crevices could cause corrosion. The weld bead is concave and has minimal ripple. These -17 electrodes give a smooth spray-transfer and produce very low levels of spatter. The acid slag tends to give the lowest carbon levels and higher silicon levels. This can be ideal for corrosion resistance, but for critical mechanical applications, the use of a -15 or even a -16 coating is to be preferred.

### Determining the Ferrite level in Stainless Electrodes:

To manually figure out the ferrite level in Stainless Steel Electrodes you would plot the Chrome (Cr) and Nickel (Ni) equivalents on the below chart.



To do so, you would use the following formula:

1)  $Cr(eq) = Cr + Mo + (0.7Nb \text{ or } Cb)$ . Plot the answer on the horizontal part of the graph by drawing a vertical line from the answer point up.

2)  $Ni(eq) = Ni + (35xC) + (20xN) + 0.25Cu$ . Plot the answer on the vertical part of the graph and draw a horizontal line from the answer point and to the right. Where Nitrogen (N) is not shown on the chemistry, use 0.07 as the average.

Where these two lines intersect on the graph is the Ferrite# on the WRC 1992 scale.

- Below is an example of using the above formula to determine ferrite#:

We have a 316L TIG rod that requires the WRC ferrite #. The chemistry is as follows:

C=0.023 Si=0.390 Mn=2.050 Mo=2.800 S=0.012  
Cr=18.530 Cu=0.270 Ni=12.050 Cb=0.023 P=0.019

1)  $Cr(eq) = 18.530 + 2.800 + (0.7 \times 0.023) = 21.33161$  or 21.3

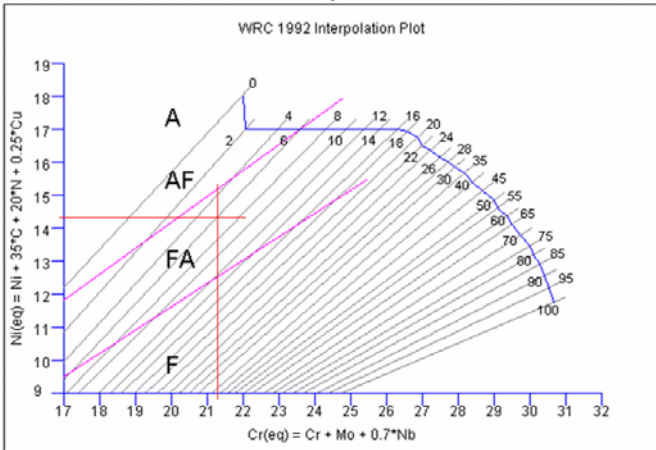
2)  $Ni(eq) = 12.05 + (35 \times 0.023) + (20 \times 0.07) + (0.25 \times 0.270) = 14.322$  or 14.3

Plot these numbers as shown on the on the following graph.



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The lines intersect on the #6 line so this material has a WRC ferrite# of ~6

An easier way is to do this is to go to the below link and fill out the chemistry fields. The built in program will then plot the data and give you the ferrite # equivalent  
<http://engm01.ms.ornl.gov/FNPLots.HTML>

The following is a filler metal selection chart for some of the more common stainless alloys. Please note that this does not take into account the specific application requirements but is just a general guideline.

Stainless Filler Metal Selection	
Stainless Type	FILLER METAL SELECTION Confirm choice with manufacturer
<b>AUSTENITIC CHROME NICKEL NON MAGNETIC</b> Stainless 201 to austenitic 200-300 series use (201 used for low temp cryo applications to -320F)	308 For 330 use 312
Stainless 202 to austenitic 200-300 series	308 For 330 use 312
Stainless 201-202-301 303 to mild steel	312
Stainless 301 to austenitic 200-300 series	308 For 330 use 312
Stainless 302 to austenitic 200-300 series	308 For 330 use 312

Stainless 302- 302B to mild steel	310
Stainless 303 to austenitic 200-300 series	308 For 330 use 312
Stainless 303 to mild steel	312
Stainless 304 to austenitic 200-300 series	308 For 330 use 312
Stainless 304 to mild steel	309
Stainless 305 – 308 to austenitic 200-300 series	308 For 330 use 312
Stainless 305 - 308 to mild steel	312 - 309
Stainless 309 to 309 - 310 - 314 - 316 - 317	309
Stainless 309 to 330	312
Stainless 309 to 347	308 - 347
Stainless 310 to 310-3140	310
Stainless 310 to 316	316
Stainless 310 to 317	317
Stainless 310 to 321	308
Stainless 310 to 330	312
Stainless 310 to 347	308
Stainless 310 to mild steel	310
Stainless 314 to 314	310
Stainless 314 to 316	316
Stainless 314 to 317	317
Stainless 314 to 321	308
Stainless 314 to 330	312
Stainless 314 to 347	308
Stainless 314 to mild steel	310
Stainless 316 to 316 - 317	316
Stainless 316 to 321 - 347	308
Stainless 316 to 330	312 - 309
Stainless 316 to mild steel	309
Stainless 317 to 317	317
Stainless 317 to 321	308
Stainless 317 to 330	312
Stainless 317 to 347	308L
Stainless 317 – 321 - 348 to mild steel	309
Stainless 321 to 321 - 347	347
Stainless 321 to 330	312 - 309
Stainless 330 to 330	330



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### Stainless Filler Metal Selection

Stainless Type	FILLER METAL SELECTION Confirm choice with manufacturer
Stainless 330 to 347	312 - 309
Stainless 348	347
Stainless 384	309
Stainless AM 350	AM 350
Stainless 501 502 430 431 442 448 to mild steel	310
17-7PH	17-7PH
17-4PH	17-4PH
Stainless to carbon	309 or 312 which has higher ferrite and reduces cracking. ENiCrMo-3 is also used when hot cycling is encountered.
<b>MARTENSITIC STEELS</b> 403 - 410 - 414 - 416- 420- 422 -431- 440 Preheat and interpass temp 500F 260C Post heat 1350F 732C> Control cool 50F / hr to 1100F> Control cool to 1100F 600C then air cool. Treat the 500 series the same as the Martensitic series	
Stainless 403 to 400 series	410
Stainless 403 to 501	502
Stainless 403 to 505	505
Stainless 405 to 505	505
Stainless 405 to 501	502
Stainless 405 to 430	430 - 309
Stainless 405 to 400 series	410
Stainless 403 - 405 - 410 - 414 - 416 to mild steel	309
Stainless 410 - 414	Weld same as 405
Stainless 416 - 440	butter with 312 or 309 first
Stainless 416 to 505 -502-501 - 446 - 440 -430 -420	309
Stainless 416 to 431-420-416	410
Stainless 420 to 505	505
Stainless 420 to 501-502	502
Stainless 420 to 446	430
Stainless 420 to 440 -420	420

Stainless 420 to 431 -430	410
Stainless 430 to 505	505
Stainless 430 to 501 - 502	502
Stainless 430 to 446 - 440 - 431 - 430	430
Stainless 430F to 400 series	309
Stainless 431 to 505	505
Stainless 431 to 501 -502	502
Stainless 431 to 446-440	309
Stainless 440	Weld same as 431
Stainless 446 to 505	505
Stainless 446 to 501 - 502	502
Stainless 446 to 446	309
Stainless 505 to 505	505
Stainless 501 to 505 - 502 - 501	502
Stainless 502 to 505 - 502	502

Austenitic stainless steel weld deposits are often used to weld the martensitic grades. These electrodes provide an as-welded deposit of somewhat lower strength, but of great toughness. For as-welded applications in which thermal compatibility is desired, the 410NiMo filler metal is a good choice.

### FERRITIC STEELS

405 - 409 - 429 - 430 -434 - 436 - 442 -444 - 446

444 to 444 or to other metal use	316L or 309MoL
Ferritic steels to Ferritic Steel	430
Ferritic steels to dissimilar metals	309 - 310 - 312

To weld the ferritic stainless steels, filler metals should be used which match or exceed the Cr level of the base alloy.

To weld the ferritic stainless steels, filler metals should be used which match or exceed the Cr level of the base alloy. To minimize grain growth, weld heat input should be minimized, Preheat should be limited to 300-450°F and used only for the higher carbon ferritic stainless steels (e.g., 430, 434, 442 and 446).

In our next issue, we will discuss AWS A5.5 “Low Alloy Steel Electrodes for Shielded Metal Arc Welding” (SMAW).