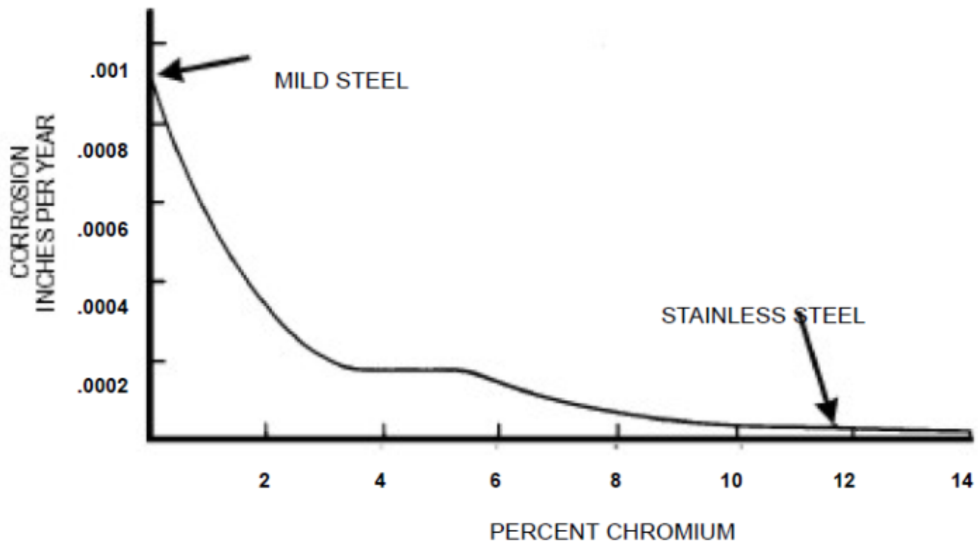
WELDING FILLER METALS FOR STAINLESS STEELS

.

Stainless steel is basically an alloy of iron and chromium. As the amount of chromium added to a steel alloy is increased, the corrosion resistance increases until the amount of chromium reaches 11% to 12%, at which point it is considered a stainless steel. The graph in Figure 1 shows how the amount of chromium affects the rate of corrosion in a semi-rural, outdoor air environment. Corrosion rate will vary with the corrosive media to which the stainless steel is exposed and with the type of stainless employed.



CORROSION RATE VERSUS PERCENT CHROMIUM
OUTDOOR ATMOSPHERE, SEMI-RURAL ENVIRONMENT

.

Stainless steel may be welded by most of the common arc welding processes. Shielded metal-arc welding with coated electrodes is still probably the most widely used process. Other commonly used processes are flux cored arc welding, gas metal-arc welding, gas tungsten-arc welding and submerged arc welding.

There are four primary grades of stainless steel: austenitic, martensitic, ferritic, and duplex.basic differences and the composition of the four types.

Austenitic – Cr (16 % - 30%) + Ni (8% - 40%) – Easily welding . No pre & post weld heat treatment

Martensitic – Cr (11 % - 18%) + Ni (0% - 5%)- Pre & post weld heat treatment is required.

Ferritic – Cr (11 % - 18%) + Ni (0% - 4%)

The behavior of stainless steel in the heat of the arc differs from that of mild steel. The rate of expansion of the chromium-nickel types is about 50% greater than that of carbon steel. This means that distortion from warping must be compensated for to a greater extent.

When welding an austenitic stainless steel to a carbon steel, the different rates of expansion can cause cracking due to internal stresses unless the proper electrode and welding procedure is used.

The expansion of the straight chromium types is about the same as or slightly less than that of carbon steels.

The melting temperature of all stainless steels are lower than that of carbon steel as and both chrome-nickel and straight chrome types are much more fluid in the melted state. Therefore, less heat (welding current) is required to weld stainless steels compared to carbon steels.

The electrical resistance of both the chrome-nickel and the straight chrome types is considerably higher than that of the plain carbon steels.

This higher resistance creates more resistance heating in the stainless steel electrode and in the base plate. Lower welding current or amperage is required to avoid overheating the electrode. The electrical resistance of the chrome-nickel alloys is about six times that of carbon steel and may be substantially higher if the stainless is cold-worked. The straight chrome types have electrical resistances varying from three to six times that of carbon steel.

The chrome-nickel stainless alloys conduct heat only 40% to 50% as fast as carbon steel and in the straight chrome types, heat conductivity is 50% to 65% that of carbon steel. This means that the heat remains in the vicinity of the arc for a longer period of time instead of being dispersed throughout the weldment rapidly, as it does when welding materials of high thermal conductivity.

This is another reason that lower amperages are required to weld these steels.

AUSTENITIC STAINLESS STEELS

Austenitic Stainless Steels are designated by a series of 300 numbers according to the American Iron & Steel Institute (AISI). Nominal compositions of some of the more important types are shown in Figure . About 80% of the stainless steel welded is of the austenitic type.

AISI No	Chromium %	Nickel %	Molybdenum %	Columbium %
301	17	7		
302	18	9		
304	19	10		
309	23	13		
310	25	20		
316	17	12	2.5	
317	19	13	3.5	
347	18	11		1

Carbide Precipitation - At elevated temperatures in the range of 800-1600°F, the carbon content in excess of 0.02% migrates to the grain boundaries of the austenitic structure where it reacts with chromium to form chromium carbide. Chromium Carbide is not corrosion resistant. Thus heat effected zone is not corrosion resistant.

Carbide Precipitation can be reduced by 3 methods.

1. Carbide precipitation is a function of the carbon content. Keeping the carbon content as low as possible in the steel (0.04% maximum) and welding it with low carbon electrodes is one solution.

2. If the carbon of the steel and weld metal are tied up by an element that has a stronger affinity for carbon than does chromium, carbide precipitation cannot occur. Columbium and titanium are alloys that have a stronger affinity for carbon. Steels with columbium or titanium, and covered electrodes with columbium present, are made for this purpose.

3. Another method, although not as practical, is to heat the finished weldment to at least 1850°F allowing all of the precipitated carbides to go back into solution. The weldment is then rapidly cooled and quenched so that it passes through the critical temperature (1200°F) very quickly, allowing little or no carbides to reform. However, stainless steel weldments heated to such high temperatures would be subject to warping, sagging and other loss of dimension as well as being covered with heavy scale.

Ferrite in Austenitic Stainless Steel - Stainless weld metal that is fully austenitic is non- magnetic and has a relatively large grain structure. This results in the weld being crack sensitive. By controlling the balance of the alloying elements in the electrode, small amounts of another phase, ferrite, can be introduced in the weld metal. The ferrite phase causes the austenitic grains to be much finer and the weld becomes more crack-resistant.

Certain alloying elements used in stainless steels and weld metals behave as austenite stabilizers and others as ferrite stabilizers. Among the austenite stabilizers are nickel, carbon, manganese and nitrogen. The ferrite stabilizers are chromium, silicon, molybdenum and columbium. It is the balance between the two types of alloying elements that controls the quantity of ferrite in the weld metal.

The amount of ferrite in austenitic stainless steel weld metal may be measured by magnetic devices because the ferrite is magnetic. A small amount of ferrite in austenitic stainless weld metal is good, because it prevents weld cracking.

If the weldment is to be in very low temperature service, however, large amounts of ferrite should be avoided because ferrite is not tough at low temperatures. Also, if the weldment is to be used in high temperature (higher than 1000°F) service, the ferrite should be maintained at low levels because the ferrite becomes brittle at those temperatures.

5.7 MARTENSITIC STAINLESS STEEL

Martensitic stainless steels fall into the 400 number series according to the American Iron and Steel Institute. They are magnetic and contain from 11.5% to 18% chromium. They have adequate corrosion resistance in many environments because they form the characteristic chromium oxide surface film.

Other chromium bearing heat resistant steels that have only 4% to 10% chromium (not a true stainless steel by the 11.5% minimum chrome requirement) have similar hardenability characteristics. These steels are designated by the 500 series numbers according to the American Iron and Steel Institute and from a welding standpoint, may be considered in the same grouping as the martensitic stainless steels. Nominal compositions of these types are shown in below

AISI No	Carbon %*	Chromium %*	Molybdenum %*
403	0.15	11.5-13	
410	0.15	11.5-13.5	
501	0.10 min	4 - 6	0.40-0.65
502	0.10	4 - 6	0.40-0.65

* Maximum unless otherwise noted

These steels are frequently in a hardened state meaning they have low ductility. If heat is applied suddenly, as in arc welding, to a localized area and it then is allowed to cool suddenly, cracking may occur. This type of cracking can be prevented by preheating the steel, since preheating lowers the thermal difference between the weld area and the base metal. This allows the weld area to cool more slowly and as a result, the steel in the heat affected zone will not be hardened as severely.

The preheating temperature used is in the range of 350°F to 500°F and should be maintained during the entire welding operation. Upon completion of welding, the weldment should be cooled slowly, preferably furnace cooled, allowing gradual temperature change.

The mechanical properties of martensitic stainless steels are affected by welding since they harden intensely, even on relatively slow cooling from high temperatures. The weld deposit and the steel that surrounds the weld deposit is hard and brittle. Heat treatment of the weldment is necessary to improve these physical properties.

If preheating or post weld heat treatment is not practical, it may be necessary to use a higher alloy austenitic stainless steel electrode (such as 309) that deposits tough, ductile weld metal without cracking. This solution would depend on the required properties of the weldment and is not recommended in all cases. Martensitic stainless steels make up about 15% of the stainless steels that are welded.

FERRITIC STAINLESS STEELS

Ferritic stainless steels are straight chrome alloys in the AISI 400 series. They are magnetic and have varying ranges of chromium content as shown in Figure 12

AISI No	Carbon %*	Chromium %*	Others %*
405	0.08	11.5 - 14.5	Aluminum 0.10-0.30
430	0.12	16.0 -18.0	
446	0.2	23.0-27.0	Nitrogen 0.25

*Maximum unless otherwise noted

Welding the ferritic high chromium stainless steels, however, is difficult. The steels have rapid rates of grain growth at temperatures over 1700°F. The large grains absorb the smaller grains and grow larger. The resultant coarse grain structures are very crack sensitive. Grain growth is a time and temperature function.

To keep the time of high welding temperature as short as possible, these steels should be mildly preheated to about 300°F, welded with small diameter electrodes and with the lowest possible welding current, thereby limiting the heat input. About 5% of the stainless steels welded are of the ferritic category.

DUPLEX STAINLESS STEELS

Duplex means "two". Duplex stainless steels consist of the two "building stones" (microstructure phases) ferrite and austenite and are often termed ferritic-austenitic stainless steels.

Typically, duplex stainless steels have a microstructure consisting of approximately 50% ferrite and 50% austenite.

In simple terms, the ferrite could be said to give high strength and some resistance to stress corrosion cracking, the austenite provides good toughness, and the two phases in combination give the duplex steels their attractive corrosion resistance.

The most important alloying elements of duplex stainless steels are Cr, Ni, Mo and N. These elements largely govern the properties of the steels. Some grades also contain additions of copper (Cu) or tungsten (W).

A wide range of different versions of **duplex stainless steel** is currently available on the market. At present, the 22% chromium (Cr), 5% nickel (Ni), 3% molybdenum (Mo), 0.15% nitrogen (N) grade (commonly called 2205) is the most common type of duplex stainless steel and is used in a wide range of applications. Higher alloyed duplex steels, the so called **super duplex stainless steels**, have also been introduced into the market. The 25% chromium (Cr), 7% nickel (Ni), 4% molybdenum (Mo), 0.25% nitrogen (N) grade (commonly called 2507) is one example of a modern high alloy super duplex stainless steel. These steels are designed for use in demanding applications where even greater corrosion resistance or higher strength is required.