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NIHONWELD

WELDING PRODUCTS

STAINLESS STEEL WELDING HANDBOOK

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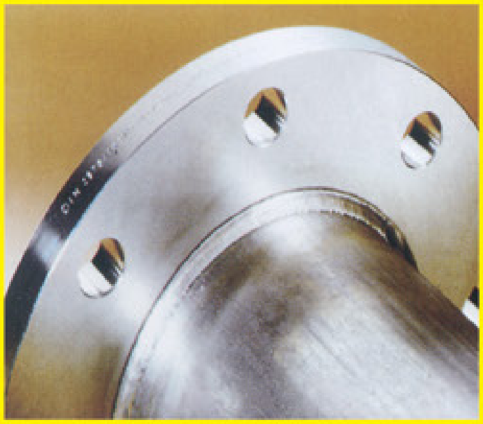

Industrial Welding Corporation

LEADER IN WELDING TECHNOLOGY

NIHONWELD

INTRODUCTION:

Industrial Welding Corporation (IWC) was established in 1982 by Mr. H. Ong Hai with over almost 50 years of experience in the welding industry. IWC's dedication and commitment to quality and research has made the company grow from a small producer to currently the biggest and most diverse manufacturer of welding electrodes/consumables in the Philippines.

IWC is the largest exporter of welding electrodes in the country, exporting to over 40 countries worldwide and continues to create new relationships in other countries every day. IWC believes in forming business relationships for long term business and friendship.

IWC will always strive and continue to improve existing products and develop new products for changing applications and needs. Quality is always first above everything else and IWC is proud to say that one can "WELD WITH COMPLETE CONFIDENCE" with our "WORLD CLASS QUALITY" products.

STATE OF THE ART LABORATORY EQUIPMENT AND MANUFACTURING FACILITIES REFLECTS OUR DEDICATION TO QUALITY, RESEARCH AND DEVELOPMENT OF NIHONWELD WELDING PRODUCTS.

APPROVALS:

AMERICAN BUREAU OF SHIPPING
BUREAU VERITAS (FRANCE)
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GERMANISCHER LLOYD (GERMANY)

NIHON WELD STAINLESS STEEL WELDING HANDBOOK

This handbook is a comprehensive compilation of data about stainless steel welding, it includes definitions, welding processes and classification of stainless steels. It also covers the problems and solution in welding stainless steels; major industries and application which can benefit economically by using Nihonweld electrodes and wires and welding systems which are use for welding high-heat, corosion and acid resistance stainless steels.

The Company Behind The Products

Industrial Welding Corporation is a leader in the field of welding electrode and wire production. This leadership was earned through years of intensive research and development. It had provided the industry with various types of welding materials and processes for weld fabrication, repair, joining, of stainless steels with the result that the metal are joined better than before.

It is the responsibility of Industrial Welding Corporation to provide creative research to expand the art of welding; to the development and production of new welding electrodes and wires which out perform traditional materials and meet the metallurgical needs of today and tomorrow.

We believe this handbook will explain the technology of welding stainless steels in alay-man language.

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What is Stainless Steel?

The general term "Stainless Steel" is the name given to a series of iron / chromium / nickle alloy, all of which show a high resistance to chemical attack and possess heat resisting properties. Chromium is responsible for the basic corrosion resistance of stainless steel and all contain more than 12% of this element.

The outstanding characteristic of stainless steels is their ability to readily form a chromium-oxide film which acts as a constant buffer against further corrosion of the underlying metal. This oxide film is stable and adherent if broken or destroyed, it reforms instantly and continuous its protective action. Increasing the amount of chromium in the steel provide increasing corrosion and heat resistance since the protective surface film is proportionately enriched. Underconditions of high temperature exposure(*between 1200-1300°F*),surface films become thicker, forming a tight,impervious seal with desirable heat resisting properties. Stainless steels which contain chromium as the main alloying element are magnetic and require pre-heating at 400°F - 600°F and a postheat treatment of 1350°F-1500°F for satisfactory quality welds.

Because of the ever increasing use of stainless steels in industry, the welder should have the greater knowledge of the various individual grades and characteristics. The following data will help the welder to recognize the compositions and characteristics of the stainless grades he may encounter. The Composition of Standard Grades of Wrougth Stainless and Heat-Resistant Steels (*AISI,1959*) is shown in Chart 1.

Metallurgy of Stainless Steels.

The addition of chromium to iron restricts the temperature range over which austenitic (*or y form*)of iron occurs.This can be represented on an iron chromium-carbon constitional diagram (*Fig.1*) from which it can be seen that in an alloy containing sufficient chromium (*about 17%*) the ferritic form persists at all temperatures.

Nickel has a similar effect to that of carbon in that it favors the austenitic form of iron. The addition of either of these elements therefore,has an effects on the constitution of the steel.
For example, a steel containing 18% chromium and 8% nickel would be fully austenitic at about 1100°C (*2012°F*).

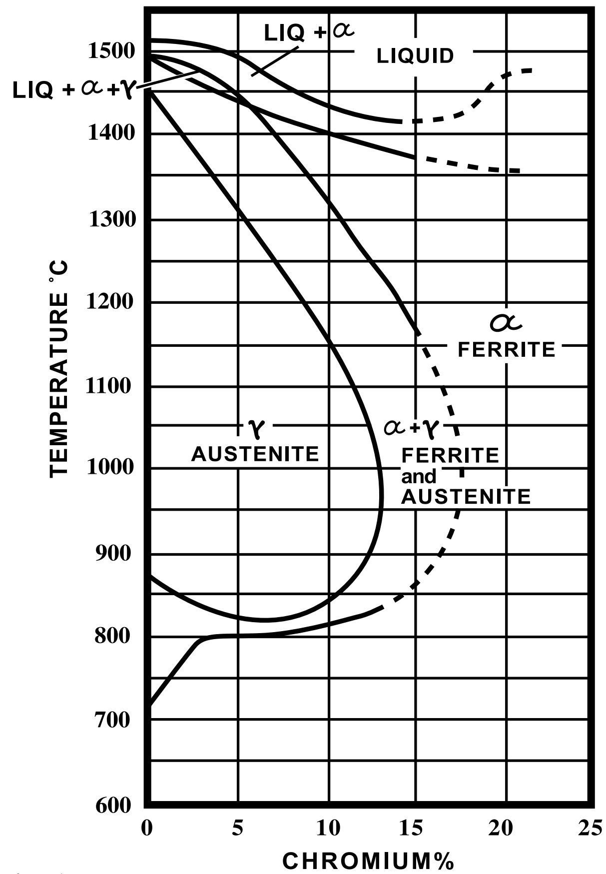


Fig. 1

A further effect of the addition of chromium and nickel is to slow down the rate transforming from austenite to ferrite on cooling and this effect occurs to such an extend in the 18% chromium 8 % nickel steels that the structure remains austenitic at room temperature even at extremely slow cooling rates.

A useful method of assessing the general metallurgical characteristics of any stainless steel is by means of the type of diagram shown in Fig. 2.

In this daigram the various alloying elements are expressed in terms of nickel and chromium; nickel equivalents for elements (*e.g. carbon, nickel and manganese*) that promote austenite, and chromium equivalent for elements (*e.g. chromium, molybdenum, silicon and niobium*) that promote ferrite. By plotting the total values of the nickel and chromium equivalents on the diagram, a point can be found that will indicate the main phases present in the stainless steels. An assessment of some of the metallurgical characteristics can be made from the phases present.

Stainless steels are classified in three general groups; Martensitic, Ferritic and Austenitic, based in composition. The steels of the lower alloy content are hardenable since they contain the martensitic phase. With increase in alloying elements the high temperature austenite and ferrite phases become more stable and the alloy ceases to be hardenable by heat treatment For this reason, steels with a relatively high level of carbon, nickel and manganese become fully austenetic (*Austenite area in Fig. 2*), while those with more chromium, molybdenum etc. tend to be fully ferritic (*Ferrite area in Fig. 2*).

Types of Stainless Steel?

Martensitic Stainless Steels.

The usual limits are 12-14% chromium and 0.08-20% carbon. (*See chart 1 for various kinds of martensitic Stainless Steels.*) There is no definite boundary composition separating martensitic and ferritic grades, the gradual transition depends largely on the chromium and carbon contents. Martensitic Stainless Steels can be hardened by appropiate heat treatment procedures and are strongly attracted by a magnet. These steels undergo hardening on cooling in air. The inside zone they become hard as it cools.

When heated to elevated temperature 950-1050°C (*1742-1942°F*) depending on the alloy composition, martensitic stainless steels transfom to the austenitic form. With rapid cooling or quenching the structure transform from an austenitic structure to an acicular martensitic structure,which is associated with a marked increased in the hardness of the material.

The degree of hardening is dependent on the carbon content. if the carbon is less than 0.1% only moderate hardening takes place.

In the as-quenced condition these steels are hard but brittle. In order to improves the ductility they are tempered. Tempering at low temperatures improves the ductility of the material with little loss in strength, but with increase in temperature there is a corresponding reduction in strength.

A typical hardening treatment for a martensitic stainless steel involves oil quenching from about 1000°C (*1832°F*) followed by tempering at temperatures up to 750°C (*1382°F*). An annealing temperature of about 750°C (*1382°F*) is used for softening these steels. The linear coefficient of thermal expansion is in the order of 11 X 10^2 (*This value is approximately equal to that for ferritic grades.*) The degree of expansion are less than those of mild steel. The hardened and tempered condition generally gives optium corrosion resistance. Although martensitic stainless are less ressistant to corrosive attack than ferritic and austenitic grades, the possible combination of high strength and useful corrosion resistance has obvious advantages. The 12-14% chromium stainless steel possess good resistance to scalling up to about 700°C (*1292°F*).

Martensitic Stainless Steels are often reffered to a Stainless Iron. Martensitic stainless steels contain alloys which cause martensite to form during cooling from the temperatures reached while welding. The martensitic structure may be excessively hard,brittle and crack-sensitive. When these steels are welded with similar weld metal it is necessary that the steel be pre-heated. if it is impossible to use preheat in the welding of martensitic steels, the weld must be made with tough ductile weld metal which stretches and does not overload the hardened heat affected zone of the steel. Nihonweld NSS-309 stainless steel electrodes provide this tough and elastic weld metal, but should not be used in circumtances where sulfur is present in service or where creep resistance and /or resistance to stress corrosion crack is required

Ferritic Stainless Steels

All steels experience grain growth at temperatures above 1700°F by the larger grains absorbing the smaller grains and becoming larger. The larger the grain,the weaker and more crack-sensitive the steel becomes.Ferritic stainless steel is exceptionally sensitive to grain growth. While chromium is again the major alloying elements, its range is increased to 17-30% in this grade. The carbon range is similar to that for martensitic steels, namely 0.08-0.25%. The martensitic and ferritic ranges of composition overlap; this overlap occurs within the chromium range of about 14-18% chromium. (*See chart 1 for various kinds of ferritic stainless steels.*)

The amount of chromium present imparts good corrosion resistance and is sufficient to cause them to be predominately ferritic at all temperatures. For this reason they cannot be hardened by heat treatment and cannot be hardened by quenching techniques.

These steels are generally classified into three groups, namely, the 17% chromium steels and the 20% chromium steels and the 27% chromium types is superior to that of austenic types above about 650°C.

If a coarse grain structure is developed in this steels, say, for example, by heating above 900°C- the structure cannot be refined solely by heat treatment; it is necessary to cold work the material prior to heat treatment. This feature is of considerable importance since the development of a coarse grain structure is generally associated with a loss in ductility.

Annealing of steels in this group is generally carried out at 750°C (*1389°F*) followed by air cooling or water quenching. Ferritic stainless steels are strongly attracted by a magnet and possess very similar characteristics to the martensitic grades. The degrees of expansion of both martensitic and ferritic stainless steels are less than those of mild steel. The incidence of warping in the weldment is thus correspondingly small. Their thermal conductivity, depending on the percentage of chromium in the alloy, varies them 1/2 to 1/3 that of mild steel.

In general the corrosion resistance of the ferritic grades increases with chromium content. The resistance of ferritic stainless steels to corrosive environment is approximately intermediate to that of martensitic and austenitic grades. A special aspect of corrosion resistance concerns the behaviour of alloys at elevated temperatures; ferritic grades are particularly resistant to oxidation under such conditions. The maximum working temperatures recommended for a particular alloy will vary over a small range, depending on the atmosphere in contact with the stainless steel. Generally, there is excellent resistance to scalling with the 17% chromium types upto 800°C, with 20% chromium up to 1100°C (*20-12°C*). At welding temperature, it occurs very rapidly. The only way to control grain growth is to use the lowest practical welding heat for the shortest possible time. This is accomplished by using as low preheat and interpass temperature as possible, small size electrodes and lowest practical welding current. Thick sections may require preheat.

Austenitic Stainless Steels

Austenitic stainless steel differs from other steels in its response to heat. The general limits of this class are 16-26% chromium and 8-25% nickel. Usually the carbon content is below 0.15%. (*See chart 1 for various kinds of Austhenitic Stainless Steels.*) For certain corrosive environments, it is necessary to use steels with alloying additions such as molybdenum stabilizing elements such as titanium or niobium are added to certain grades to inhibit undesirable forms carbide precipitation within the structure of the alloy.

Nickel additions in stainless steel are always supplementary to chromium.However such additions profoundly affect the resulting steels. Corrosion resistance is substantially improved since the protective film containing both chromium and nickel is far more corrosion resistant than in the case of the martensitic and ferritic stainless steels. This corrosion resistant property is generally good up to about 850°C (*1562°F*). Nickel addition also impart several other important physical properties to stainless steels.

Provided the alloy contains sufficient amounts of nickel, the stainless steel structure becomes austenitic, non-magnetic, non-hardening by heat treatment, non-air hardening, and unusually tough and ductile. It retains its high degree of ductility in high temperature applications

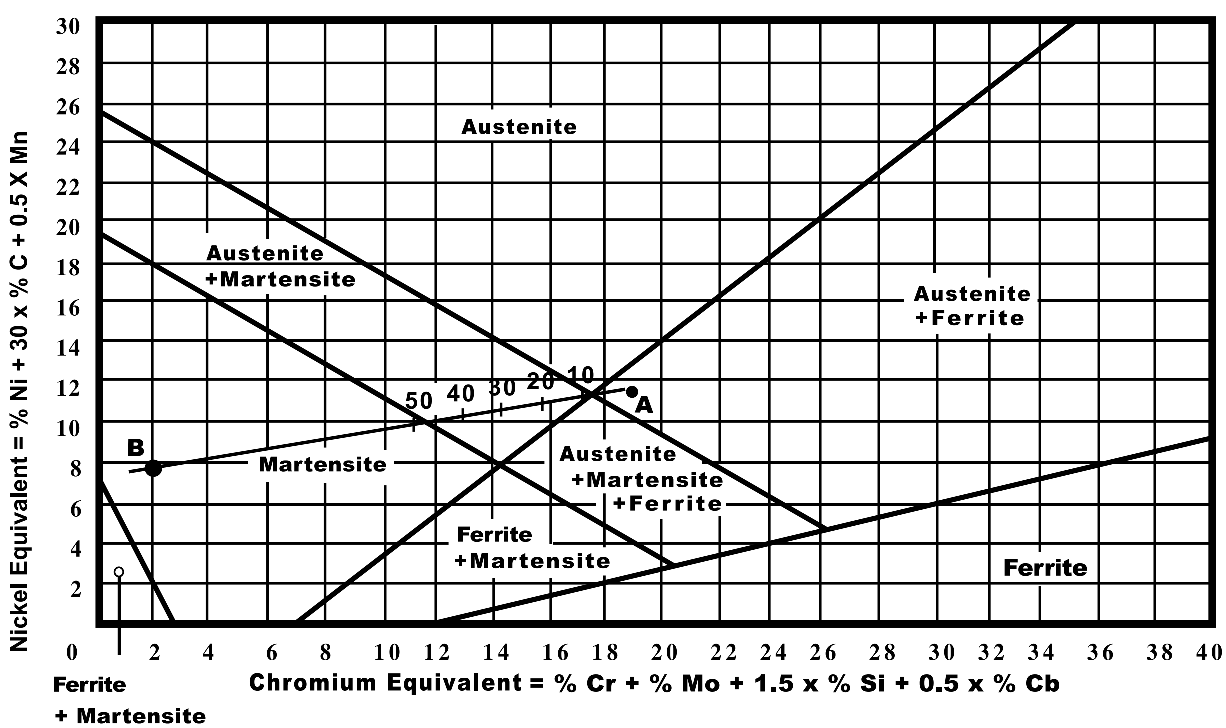


Fig. 2 Chromium - nickel equivalent diagram

and possess better welding characteristics than the martensitic and ferritic stainless steels. These valuable properties, combined with outstanding corrosion resistance render chromium-nickel grades useful for a variety of applications. Additions of 2-4% molybdenum increase the resistance to non-oxidizing acids,particularly to sulfuric acids of low concentrations. There are several other elements which are always present in smaller quantities (*trace elements*) or intentionally added for specific purpose. These include chiefly manganese, silicon, copper and alluminum. Added in sufficient quantities each introduces modifications to the major characteristics of stainlees steels.

Austenitic stainless steels are widely used in all types of industries. The range extends from the common 18/8 (*18% chromium and 8% nickel*), grades of the 300 AISI series to the more sophisticated proprietary grades. The austenitic (*non-magnetic*) stainless steels are characterized by these additional physical properties affecting welding procedure:

a.) The degree of expansion is 55% higher than that of mild steel. It has a linear coefficient of expansion in the region of $17x10^{-6}$ Allowance should be made for greater thermal expansion; increase the gap between plates slightly while welding. It is recommendeto use tack welds liberally to prevent warping and where possible use jigs and clamps.

b.) It has much lower thermal conductivity than steel, causing the weld areas to remain hot longer. Because of slower heat dissipation, distortion is potentially greater (*the thermal conductivity is half that of mild steel*). Necessary precautions must be taken to prevent warping or distortion due to welding heat.

c.) Austenitic stainless steels will not air-harden nor respond to heat treatment. The electrical resistance of austenitic stainless is several times greater than carbon steel which limits the amount of welding current usable with a stainless electrode without overheating the electrode.Austenitic stainless steels derive their name and potential from additions of modifying austenite formers. While nickel and manganese may be added in relatively large quantities, the use of carbon and nitrogen is limited by their solubility and possible side effects. Ferrite forming elements in austenitic stainless steels are chromium,molybdenum, silicon, columblum and titanium. The presence or absence of ferrite is mainly the result of the proportion of chromium to nickel (*depending on the composition balance*). A single type of weld material may be fully austenitic or partially ferritic. Fully austenitic weld deposits are occasionally susceptible to "hot-short" cracking. The presence of ferrite inhibits this tendency to crack. The weld metal composition (*in most cases*) is such that ferrite in amounts of 5 to 10% or higher will be present in the deposit to assure freedom from hot cracking or microfissuring in the weld metal.The Scheaffler diagram is the best known aid to determine the ferrite content.

When an austenitic stainless steel is high in chromium content and low in nickel, ferrite shows up as a magnetic structure. When this alloy is subjected to long periods at temperatures between 1200 and 1700°F, an intermetallic compound of chromium and iron, called the 'sigma phase" may be encountered. The "sigma phase" may cause loss of corrosion resistance, and more difficulties could arise through loss of ductility and impact resistance. The use of completely ferrite-free weld filler metals precludes the formation of sigma phase.

But no real benefit may result from their use since the tendency to form "hot-cracks" in the weld metal increases as the proportion of ferrite decreases. When the occurence of "sigma phase" is deemed harmful, it is well to remember not to use weldfiller metals containing in excess of 6% ferrite. If cracking makes higher ferrite ratios necessary, it is important to know that sigma maybe dissolved in austenite or converted into delta-ferrite by heating to above the maximum temperature of stability of sigma. Such heating causes the original properties to be substantially or wholly restored. Ductility can be considerably restored to steels by heating for as short a time as ten (*10*) minutes at 1900°F. Total conversion of sigma requires heating to 2250°F (solution annealing). The optium temperature depends on the particular grade of the stainless steel. The weldment must be cooled rapidly through the sensitization range (*900-1500°F*) to avoid carbide precipitation.

Major Types of Stainless Steel Corrosion and Their Preventive Measures

_Uniform Corrosion. When the surfaces of stainless steel is attacked uniformly by a corrosive medium, it is called uniform corrosion. In such cases, it is necessary to select the proper materials and the proper electrodes suitable to the specific corrosive environment. For strong oxidizing acid such as nitric acid, it is advisable to use ferritic stainless steels and for the non-oxidizing acid or reducing acid like dilute sulfuric acid or acetic acid the 316 type with addition of Ni, Mo or Cu is used. In some uncritical case 308 type is also commonly used.

_Pitting Corrosion. When the surface of stainless steel is corroded dottedly pinhole like it is called pitting corrosion. This is the result of incomplete surface coating of the stainless steel to with stand corrosion. If this happen, it is necessary to remove the effects of strain and precipitates by heat treating.

_Intergranular Corrosion. When austenitic stainless steel is heated at 550-800°C temperature, chromium carbide precipitates in grain boundary. Because of this phenomenon, grain boundaries are easily attacked by a corrodent and become unbrittled. To overcome this intergranular corrosion, it is necessary to dissolve the carbides in austenitic structure by quenching from 1050°C or to use the low carbon electrodes or electrodes stabilzed by Nb or Ti.

_Stress Corrosion Cracking. Stress-corrosion cracking arises from the stress which is remained in base metal or stress applied dynamically. For example it arises in corrosive environment where chlorine iron is present, in these cases, it is effective to do the stress- relieve treatment by rapid cooling for 800°C or to use the high Ni containing austenitic steel.

_Crevise Corrosion. If foreign materials or scales remain in the stainless surface, oxygen deficiency in the surface can be deteriorate the corrosion resistant coating of this surface. This type of corossion is called the crevise corrosion. It is necessary to keep the surface clean from dirt, scale or other foreign materials in order to avoid this type of corrosion.

_Corrosion Fatigue. When parts is subjected repeatedly to stresses, crack sometimes occur due to these stresses after a short period of usage. In these cases, it is necessary to keep the stresses within the fatigue range of the materials. Take care not to make notches which maybe the original points of failure.

_Dry Corrosion. When metals are red heated at high temperatures, scales are formed in their surface and peel off. This is the type of corrosion called dry corrosion. A general heat resistant steel like high chromium steels and ferritic stainless steels are used to avoid this corrosion. However some austenitic steels are widely used as heat resistant steels.

Nihonweld Products Give Top Quality Welding on Stainless Steels.

Thru years of intensive research, Industrial Welding Corporation has developed high quality **NIHONWELD** welding and filler materials for the field of Welding Stainless Steels. It has produces welding products that gives precise chemical analysis to withstand the tough heat and corrosion test in various types of stainless steels. Description and application data of this products are found in pages 10 to 13 of this text, Industrial Welding Corporation can also design specific stianless steel welding materials can meet the customers particular chemical and mechanical requirements.

Welding Processes for Joining Stainless Steels

Stainless steels can be welded by all methods applicable to carbon steel with the exception of hammer or forge welding. Some of the most common methods are briefly described under the following headings:

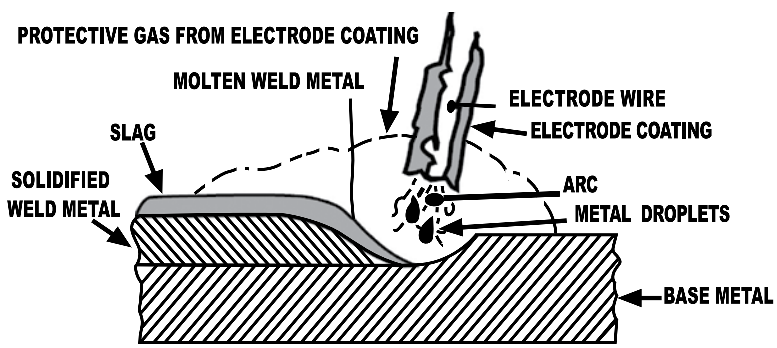


Fig. 3

Metal Arc Welding

Fusion welding by metal arc provides instantaneous heat at the point needed for just the right length of the time and provides quick dissipitation and minimum heat build up.

Metal arc electrodes are coated with prepared flux which rises to the top of the pool and protects the deposit from oxygen and nitrogen as the beads cools.

Direct current is preffered to alternating current in metal arc welding and the use of reverse polarity is recommended with a few exceptions where heavy sections are encountered. Reversed polarity (*electrode positive and work negative*) usually has sufficient weld penetration due to the poor heat conductivity of stainless steel. Only in unusual cases will straight polarity be required for better fusion and penetration. Twenty percent less current than that ordinarily used for plain carbon steel is recommended when welding stainless steel. This is due to the lower melting point for stainless as opposed to plain carbon steel and the lower thermal conductivity of stainless which localizes heat from the arc, thus lowering the current requirements.

In arc welding, it is important that the material be free of scale, grease or any dirt that may cause contamination of the weld. The flux coated electrodes are of a special analysis to compensate for the loss of chromium and other elements when passing through the arc. It is imperative that the electrodes be kept clean and dry as the coating will pick up moisture unless properly stored. (*See Fig. 3*)

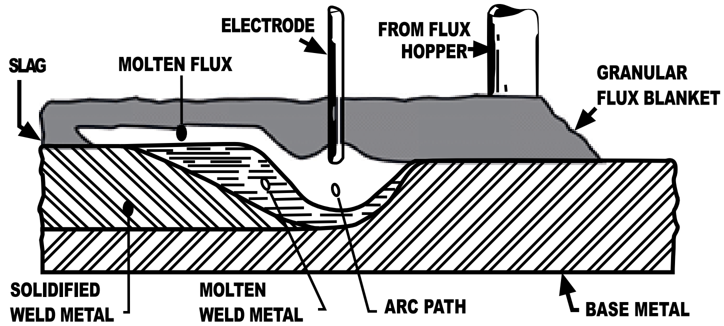


Fig. 4

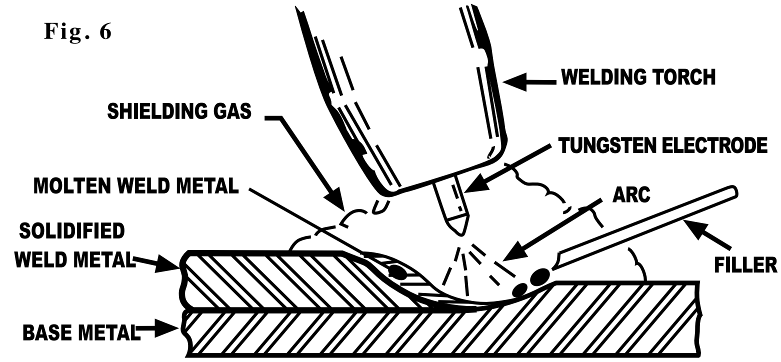


Fig. 6

Submerged Arc Welding

In submerged arc welding, automatic or semi-automatic welding machines are available and like metal arc welding, either direct or alternating current may be used.

Bare stainless steel electrode wire is fed to the joint from a coil and at the same time, a mound of granulated flux is fed over the joint. Thus, as welding progresses, a portion of the flux melts and the welded area is completely submerged in molten slag. The blanket of flux serves as a medium through which the electric current passes and blankets the top surface of the weld, preventing atmospheric gases from contaminating the metal. It also dissolves and thus eliminates impurities that separate themselves from the molten steel, and float to the surface. This can be the vehicle for adding certain alloying elements to the weld. Much higher welding currents may be used with consequent deeper weld penetration. Infact, the deep welding characteristics of this method make it possible in many cases to weld with little or no edge bevelling.

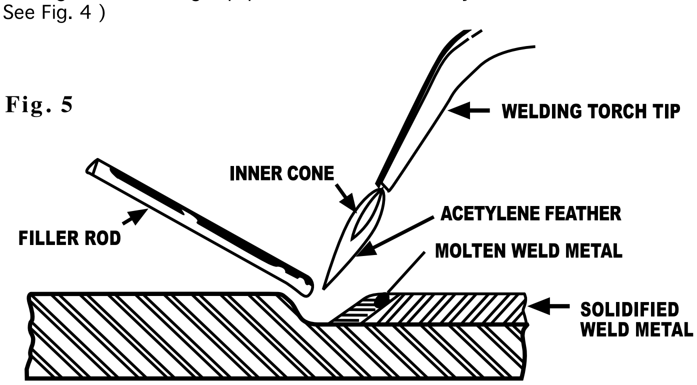
After the weld joint has been completed, the unmelted flux or powder is returned to the hopper for re-use and the fused slag is taped off the top of the weld bead. Manufacturers' instructions for operating and adjusting submerged arc welding equipment should be closely followed for best results. (See Fig. 4)

TIG Welding

Tig welding is carried out in an atmosphere of inert gas, usually helium or argon to protect the weld zone from undesirable atmospheric pick-up at the weld zone. The equipment consist of a torch like head with a single tungsten electrode mounted at its center. An intense electric arc set up between the virtually non-consumable electrode and at the work piece provides the necessary heat for welding. Both helium and argon are satis-factory for this type of welding. Argon is often used because considerably lower flow rates are required with this sheilding gas. A mixture of two gases provides best results in many applications. The proportion of each are best determined by experience and observation. Electrode diameter and the gas cup sheild will vary with the material being welded and best results are obtained by following the instructions of the torch manufacturer. This method is highly recommended for welding of light gauge stainless sheet and has been successfully applied where other methods have failed due to the thinness of the section.

A new variation in Tig Welding involves the automatic highspeed introduction of .045 diameter filler wire which is separately melted by induction and added to the weld puddle. It is referred to as Tig Hot Wire Welding and can greatly increase the deposition rate and welding speeds (See diagram above).

Fig. 5



Gas or Oxygen-Acetylene Welding

Oxy-acetylene welding is usually confined to the welding or light sections of the chromium-nickel 300 series stainless steels. Other methods such as metal-arc or atomic hydrogen welding, if possible, are preferred.

In acetylene welding, the nature of the flame is very important:

a.) If the flame is to rich with acetylene, it will make a brittle weld and result in impaired corrosion resistance because of carburization.

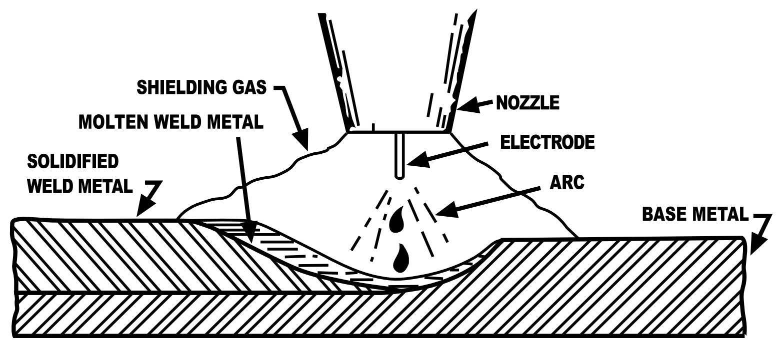
b.) If it is too rich with oxygen, it will make and oxidized or porous weld. Therefore, the flame should approach a neutral condition as closely as possible. It is usual practice to adjust the flame to a neutral or slightly carbon pick-up is less critical than porosity and a lack of soundness in weld.

c.) The size of the flames should be compatible with the job, but extra large flames should be avoided.

Other Recommendations:

_Bare rods of the same analysis as the steel being welded should be used.
_A flux applied to the underside, close to the edges being welded results in a smoother and better weld and a number of commercial fluxes are available for this purpose.
_The diameter of the rod should be about the same as the thickness being welded, so that unequal lengths of time for heating will not be required.
_Clamps should always be used to minimize buckling or distortion and the material to be welded must be free of oil, grease of dirt that can cause contamination of the welds.
_Chill bars or plates are helpful in preventing distortion and once the weld is starded, it must be finished as rapidly as possible. (See Fig.5)

Fig. 7



MIG or Gas Metal-Arc Welding

Mig or gas Metal-Arc welding differs from the Tig process in that the electrode is melted. A gas shielded arc is maintained between the workpiece and a consumable, bare wire electrode from which metal is transferred to the workpiece. The molten weld puddle is protected by inert gas which prevents atmospheric oxygen and nitrogen from combining with the molten weld metal. The coiled, automatically driven electrode wire is generally of the same composition as the stainless alloy being welded. Mig welding is about four times faster than the gas tungsten arc methods and, using variations in the process of metal transfer, this method is widely employed in the welding of stainless steel particularly in the fabrication of light gauge sheet and strip (See Fig.7)

Electron Beam Welding

Electron Beam Welding is a fusion-joining process in which the workpiece is bombarded with a dense stream of high velocity electrons and virtually all of the kinetic energy (energy of motions) of the electrons is transformed into heat upon impact.

The heart of the process is the electron beam gun. There are many designs, but all have the basic purpose of emitting electrons and focusing is accomplished with electromagnetic coils.

Conventional welding techniques tend to melt only the surface of stainless steel so that penetration essentially comes by heat conduction. Electron beam welding, by contrast is capable of such intense local heating that it instantaneously vaporizes the metal so that the hole is formed through the entire thickness. For example, a 1/16" wide weld may be made in 1/2" plate. The walls of the pierced hole are molten and as the beam advances, the molten metal flows from the front to the rear of the hole where it solidifies. All welding takes place in a vacuum or low vacuum chamber.

This is rapid, precise, controllable process which produces exceptionally high quality welds while minimizing distortion and other adverse effects on the workpiece.

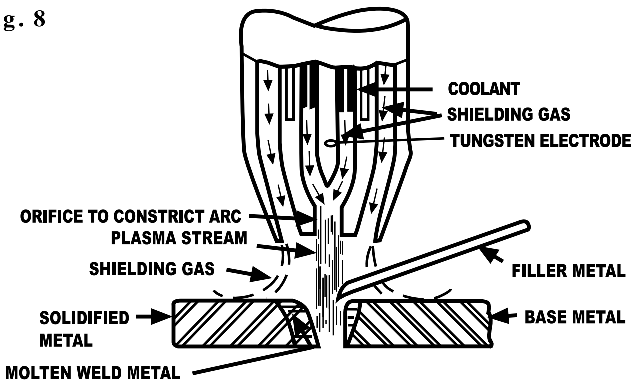
As with any other process, equipment must be carefully selected and tooled in order to receive the full potential of electron beam welding.

Plasma Arc Welding

Plasma arc welding is an inert gas, non-consumable electrode welding method utilizing a transferred constricted arc. As the inert gas passes through the torch to the work, it is heated by the arc, expands, and passes through the arc constricting nozzle at an accelerated rate. The of gas flow is limited, since too high a flow would cause turbulence in the molten puddle. Since there is not sufficient gas to protect the molten puddle from atmospheric contamination, auxiliary shielding gas is provided through an outer gas cup on the torch. Underbead gas shielding is generally required to protect the molten underbead from atmospheric contamination.

Mechanized equipment must be used to achieved the welding speed and penetration advantages associated with plasma arc welding.

Fig. 8

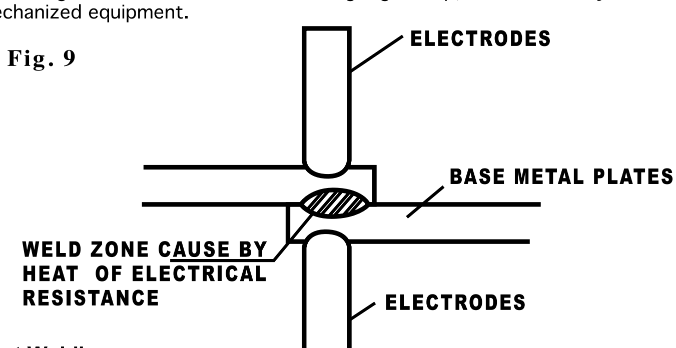


Mixture of argon and hydrogen gas and the shielding gas are utilized. In general, the premissible percentage of hydrogen (5 to 15 percent) in the gas mixture increases as the thickness of the workpiece decreases.

The welding of very thin sections requires the use of low arc currents. Filler metal in the form of wire can be added in the same manner as with TIG arc welding.

This low current plasma arc welding system has been used successfully in making butt welds in foil and thin gauge strip, both manually and with mechanized equipment.

Fig. 9



Spot Welding

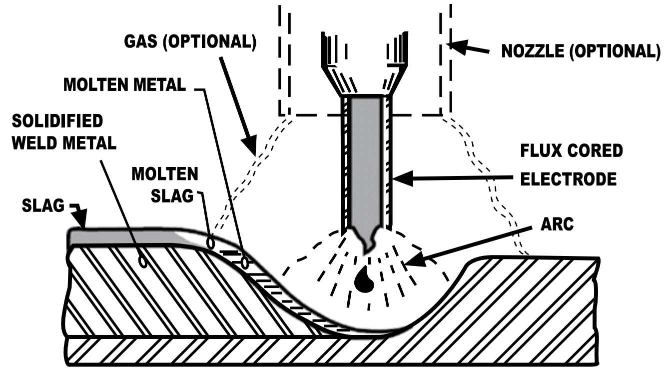
The simplest form resistance welding is spot welding. A single spot weld is made between two flat pieces of metal by clamping them together between the ends of two rounds bar electrodes, applying pressure and passing a current across the gap at the contact, holding for an interval and then removing.

There are three factors to bear in mind when compairing spot welds in stainless with those in low carbon steel.

_Electrode pressure must be at least 50 percent higher than with mild steel and must be uniform.

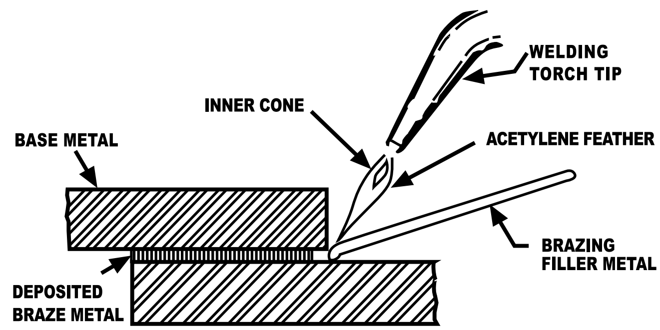
_Amperage and current flow times are both lower than those used for mild steel

_Timing accuracy is a necessity and any equipment used should be capable of controlling the time within very close limits. (See Fig. 9)



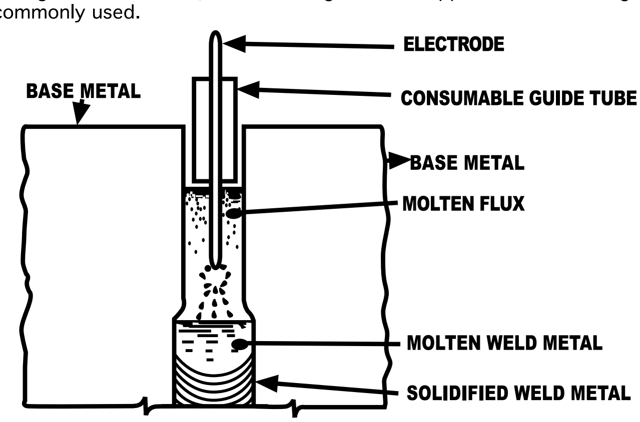
Flux Cored Arc Welding

Flux cored Arc Welding is an electric arc welding process which fuses together the parts to be welded by heating them with an arc between a continous flux filled electrode wire and the work. Sheilding is obtained through decomposition of the flux within the tubular wire. Additional sheilding may or may not be obtained from an externally supplied gas or gas mixture. The process is normally applied semi-automatically, but can be applied automatically or by machine. It is commonly used to weld medium to thick steels using large diameter electrodes in the flat and horizontal position and small electrode diameters in all positions. The process is used to a lesser degree for welding stainless steel and for overlay work. The skill level required for Flux Cored Arc Welding is similar to MIG.



Torch Brazing

Torch brazing, sometimes called Gas Brazing, is similar to Oxy-acetylene Welding, except the base metal is not melted, and the filler metal is usually a nonferrous metal. The filler metal flows into the joint by capillary attraction. Brazing can be done in all positions on most metals including stainless steels and is specially popular for repair work on cast iron.The process is normally applied manually and requires a relatively high degree of brazer skill. In brazing stainless steels, silver brazing rods or copper rods containing silver are commonly used.



Electroslag Welding

It is a welding process which fusses together the parts to be welded with molten slag which melts the filler metal and the surfaces of the work to be welded. The molten weld pool is shielded by a slag covering which moves along the hoint as welding progresses. The process is not an arc welding process, except that an arc is used to start the process. After stabilization the molten slag provides the necessary heat for welding.The process is always applied automatically. It is a limited application process used only for making vertical welds on medium to heavy thickness of mild steel. Manual welding skill is not required, but a technical knowledge of the process is required to.

Projection Welding

Projection welding is a variation of spot welding whereby two or more spot welds are produced at one time. Little protuberances are pressed into one of the workpieces at the locations to be welded. Welding electrodes are more complex and are made to suit the particular job. Electrode pressure is generally lower, but current requirements are higher due to the greatly increased contact areas. Contact electrodes should be of a hard copper base alloy with an electrical coductivity not less than 30 percent of copper. Of action as to greatly curtail the adverse effects of high metal temperatures on corrosion resistance. The high electrical resistance, low heat conductivity and good forgeability of the stainless steels account for the success of this method in the joining of stainless steels.

Butt Welding

Two types of resistance butt welding are used for joining stainless steel end to end. They are referred to as "upset butt" and "flash butt" welding. Similar equipment is used for both types of welding, but different techniques are employed.

Flash butt welds are achieved by the heat obtained from the resistance to the flow of electric current between the two surfaces and by the application of pressure.

After the work parts are heated sufficiently by the "flashing" clamps move toward one another and displace some of the heated metal and a weld results.

In upset welding, the force is applied before heating is started and is maintained throughout the heating period. No arching or flashing takes place.

Flush butt welding methods applied to stainless steel are essentially the same as those use for carbon steel. However, certain modifications in time, heat and pressure are necessary.

a.) Current requirements are about 15 percent less.
b.) Considerably more upsetting pressure is required and there should be at least 50 percent higher clamping pressures than with plain carbon steel.

Flash butt welding machines are capable of performing additional operations such as pre and post heating and hence, lend themselves to use on some of the hardenable 400 Series grades.

Problem and Solution in Welding of Stainless Steels

In a weld, complete range of conditions can occur, from a "cast" structure in the fusion zone, to the parts of original tube which have been heated to various temperatures (Fig, 10, 11, 12). The behaviour of the metal under these conditions of heating and subsequent cooling determines to a large extent the success or otherwise of the resulting weld. Since the response of the metal during welding is governed by its physical and mechanical properties and its metallurgical characteristics, it is important to discuss these factors in so far as they affect the welding operation.

The problem which are encountered in the welding of stainless steels vary accordingly to which the steel belongs, i. e. whether martensitic ferritic or austenitic. In many instances, the martensitic and ferritic stainless steels are welded with an austenitic electrode, because of the non-hardening aspects of the weld deposit of these electrode. Sometimes the joining is done with an austenitic electrode and the top layers welded with a straight chrome type. Before making a recommendation, it is absolutely necessary that the end use of the finished weldment be determined, particularly for applications where the effect of nickel in the weld material might be objectionable from a corrosion standpoint.

Welding of Martensitic Stainless Steels

The common feature of martensitic stainless steels is their tendency to harden when cooled from high temperatures. Consequently, in this group the hardening effect in the parent metal adjacent to the weld is the prime difficulty. In order to reduce the hardness in the heat-affected zone and the parent metal, it is advisable to preheat the joint at 200°C (392°F) so reducing the temperature gradient, and apply post-heating at 750°C (1382°F). In the latter case the temperature must not exceed 800°C (1472°F) otherwise austenite may reform. (See chart 2 for proper pre-heat and postheat treatment).

The tougher weld can be obtained by using an austenitic filler, but a subsequent stress-relieving anneal is still necessary. The difference is thermal expansion, however, between the base metal and filler material may jeopardize the mechanical strength of an assembly subject to repeated heating and cooling cycles. If the stainless steels are to operate in a sulphurous-gas atmosphere the filler material should preferably not contain nickel because of the inherent risk of corrosion. The use of austenitic electrodes should be carefully deliberated in each particular case.

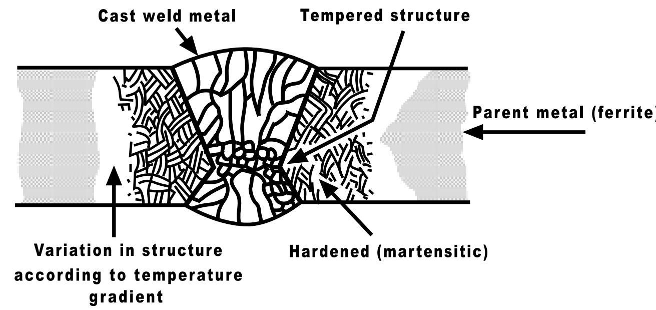


Fig. 10 Typical welding structure of martensitic Stainless Steels CR = 12 - 14%, C = 0.80 - 0.20%.

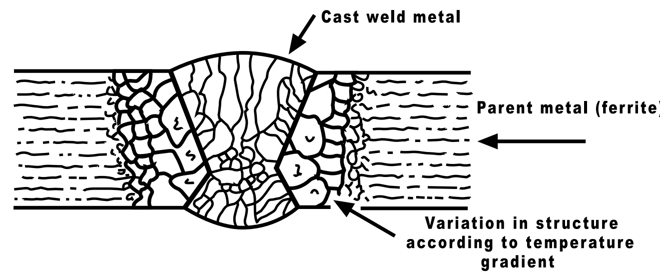


Fig. 11 Typical welding structure of Ferritic Stainless Steels CR = 17 - 30%, C = 0.08 - 0.25%.

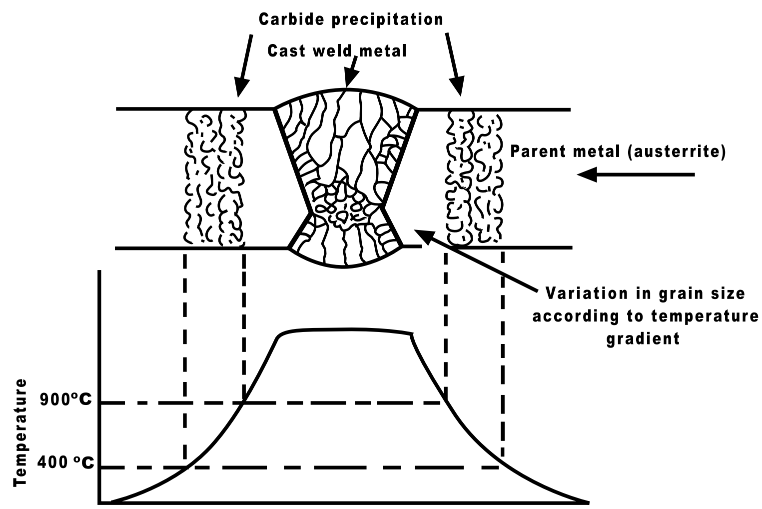


Fig. 12 Typical welding structure of Austenitic Stainless Steels CR =16 - 26%, Ni = 8 - 25%, C = 0.1%.

Welding of Ferritic Stainless Steel

With these steels the hardening effect in the heat affected zone is not significant. The prime difficulty is the brittleness which can develop in the heat affected zone when these grades are heated above about 1100°C (2012°F). This brittleness has at one time thought to be used solely by the development of a marked grain growth, but is now believed to be associated with a more complex metallurgical phenomenon. Some martensitic also forms during the cooling period. Annealing at approximately 750°C (1382°F) followed by air or water quenching will improved the ductility reduce stresses and removes hard martensite but a fine grain structure cannot be fully recovered. A post weld treatment serves to reduce stresses and removes the hard martensite. It does not however, reduce the grain size of the coarsened ferrite grains.

Ferritic steels with high chromium contents such as type 446 (27% chromium) are inherently brittle below some 150-200°C (302-392°F). Type 446 should, therefore, be pre-heated to at least 200°C (392°F) before welding. Similarly the straigthening of a welded structured produced in a high chromuim material should only be undertaken after pre-heating to approximately the same temperature to avoid brittle fracture. (See chart 2 for proper pre-heat and post-heat treatment).

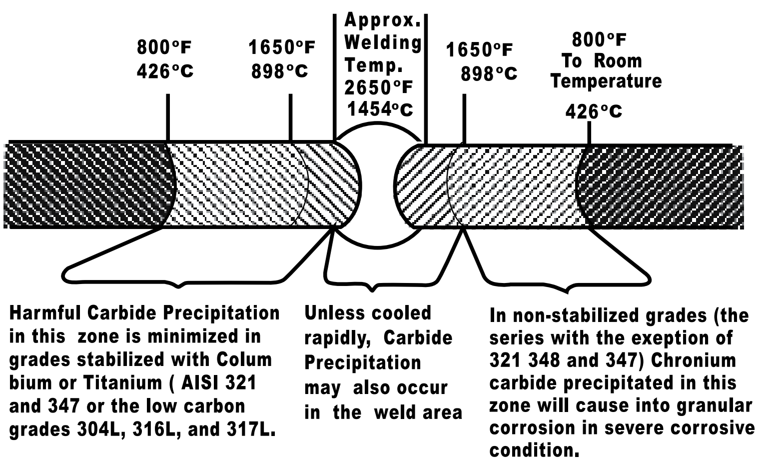
Welding of Austenitic Stainless Steel

The third group of steels, the austenitics, are much more amenable to welding than other two, partly because they suffer no hardening effects in the heat affected zone of the parent metal. Hence grain growth and possible embrittlement lack importance.

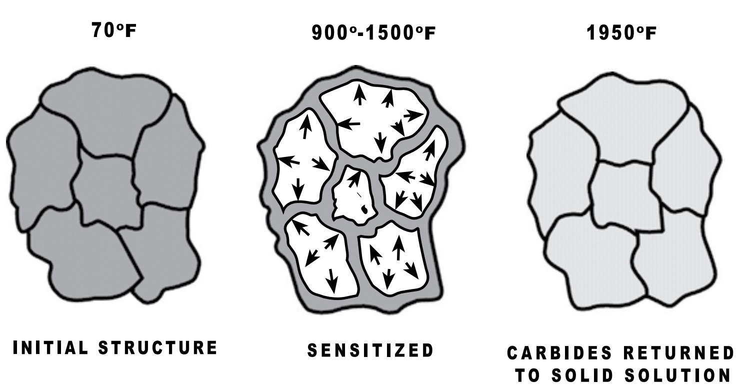
They have however, a high coefficient of expansion and considerably lower heat conductivity than the other steels. This means that distortion is a problem. Austenitic stainless steels maybe welded by any common welding processes. The most suitable welding processes are those which produce instantaneous, localized heat. This is the reason why gas welding is not particularly useful in joining austenitic chromium-nickel stainless steels. It can be used for joining thin gauge material if no other choice is available. Stabilized and low carbon grades are definitely preferred for gas welding.

The extreme problem with the welding of austenitic chromium-nickel stainless steel is their tendency to CARBIDE PRECIPITATION. Because carbon has a higher affinity (chemical attraction) for chromium, (the funda-mental element in stainless steel which assures corrosion resistance) than it has for iron, the carbon combines readily wuth chromium at high temperatures. As the base metal cools down after welding, it goes through a critical range which occurs between 900°F and 1500°F. At these temperatures, the carbon combines with the chrome at the grain boundaries to form chromium carbides. Chromium carbides cause a depletion of chromium in the heat affected area, leaving the metal chromium poor and reducing the corrosion resistance. In effect, the depletion of chromium content may lead to INTER-CRYSTALINE CORROSION or sometimes known as WELD DECAY.

CARBIDE PRECIPITATION ZONES DURING WELDING



Below is a typical molecule of stainless steel magnified 800x;



To offset this carbide precipitation, the following is suggested:

_If regular carbon grades of stainless steel are welded, a post fabricating or post-welded solution heat treatment at 1900°F can be applied to dissolved any precipitated carbides. Immediately follow this with a rapid quenching thru the sensitization temperature range creates insufficient time for any new carbide precipitation occur.(This method maybe impractical for massive structure. (See chart 2 for proper pre-heat and post-heat treatment).

_Another easier method is to use stainless steel alloys (both base and filler metals) with low carbon content, not in excess of 0.04%. The designations for these alloys are L for low carbon or ELC extra low carbon. Carbon precipitations in the transition zone is slight with such as low carbon content.

_A third option is to apply grades immune to carbide precipitations. Elements such as columbium (niobium) tantalum and titanium are strong carbides formers. They stabilize the carbon by joining with for carbon in place of the chromium.

Austenitic stainless steels which contains additions of such elements are termed "stabilized" steels. Since these elements do not affect working, fabricating and physical properties of stainless steels, they solve one of the most serious problems in the application of the steels. These grades of steel have become indispensable in many applications. They are preferred over low carbon grades of stainless steel when the end products must work within the sensitizing range of 900 - 1500°F. At elevated temperatures the corrosion resistance and greater strength of these steels are sometimes an advantage. Columbium, together with tantalum, is used in amounts of 10 times the carbon content for stabilizing purposes. High crack resistant welds metal are preferably alloyed with small amounts of colubium so they require less than average amount of carbon also. Titanium is used only for stabilizing AISI 321 type stainless metal. A columbium grade electrode must be used on 321 type stainlesssteel.

Welding of Dissimilar Metals Using NIHONWELD Stainless Steel Arc Welding Products

In welding the austenitic 300 Series stainless grades to carbon or low alloy steels, it is customary to use a stainless steel welding rod that is sufficiently high in total alloy content to prevent martensite formation when diluted with carbon steel, while at the same time, preserving residual amounts of ferrite which counteract the tendencies for hot cracking during welding. Both NSS-309, NSS-310 and NSS-321 electrodes are used for this purpose. Type NSS-309 is the more commonly used.

Carbon steel or low alloy weld metal should never be deposited on stainless steel. The welding of the 400 Series grades to carbon steel can be accomplished using electrodes such as NSS-309.

The same technique is employed when overlaying stainless on carbon steel. For the first layer, Types NSS-309 cb or NSS-312 commonly used by fabricators. For the second layer, NSS-308L or NSS-308 are commonly used. Type NSS-308 is not recommended for the first layer over carbon steel as it is not sufficiently high in alloy to prevent harmful dilution. In case of dissimilar metal welding.

It is necessary to consider the selection of electrodes rod penetration percentage in order to maintain a weld metal in the safer zone. For example consider A (shown in figure 2 the composive of the weld metal 19-9 stainless steel) and 0 (showing the composition of base metal). When the base metal (shown by 0) is welded with the electrode (shown by A), the structure of weld metal by the variation of penetration is shown along the line connecting A and 0, therefore if penetration percentage is 30% then the compositive of the weld metal will be found on B which consist of A and M. And the contents of each elements of weld metal can be calculated by using the following formula.

$$C_W = C_f + \left(\frac{P}{100}\right)^n (C_p - C_f)$$

- Cw: Content of some element included in the n-th layer deposited metal (%)
- Cf: Content of some element included in the deposited metal without dilution (%)
- Cp: Content of some element included in the base metal (%)
- P: Penetration percentage
- n: Number of layers

Using the above formula and Schaeffler's (see Fig.2) diagram, select the suitable electrode considering the composition of base metal, welding condition and application, etc.

SEVEN (7) Points to Consider in Welding Stainles Steels

1. The diameter of the electrode should be equal to the thickness of the metal to be welded. Bigger electrode will require higher welding current. Excessive current will cause the electrode to pierce or cut into the welded piece.
2. Do not use electrodes that are excessive moisture. Re-dry moisturized electrodes at 150-200°C for 30-60 minutes before welding.Excessive moisture will sometimes cause blow holes in stainless steel welds.
3. Use the lowest possible welding current to avoid overheating of the electrodes. Overheating is often encounter in stainless steel welding because of the high electric resistance of the core wires used in most stainless steel electrodes. Overheating will often degrade the composition of the weld metal and will decrease the corossive properties of the weld metal.
4. Avoid continous welding and keep the temperature of the weld piece under 150°C to minimize slag inclusions. Slag inclusion gathered in the austenitic grains will sometimes cause cracking between the boundary of the base metal and weld metal when cooled after welding.
5. Heavier material should be bevelled with a 30 angle on each edge to form a 60 "V" when the edge are joined. Very heavy stock 3/4" to 1 is generally bevelled both sides with either "V"shapes grooves.
6. When the section or material exceeds 1/4 thickness, two or more heads will always be required as cracks due to shrinkage may result from excessive exposure to the metal arc when trying to make one piece do the work of two or more. If two or more passes are required all slag must be removed before depositing the next bead.
7. This stock should be clamped firmly to prevent buckling or warpping. Material .060" and under should be butted together without an opening. For lighten materials tacks weld at short intervals are recommended. Stock over 0.06" and up to about .187" is usually vee up with an opening equal to about 1/2 the thickness of the stock.

The Selection of Stainless Steel Filler Metal

The choice of electrode to use in welding stainless steel depends upon three factors: The first is the composition of the stainless steel or of both steels in the case of a dissimilar joint to be welded. Refer to chart 3 for the application guide for Nihonweld stainless steel welding products. The second is the service conditions the weldment will see after fabrication. The third is the need for crack resistant weld metal. This can be controlled by the presence of ferrite (3 to 8 FN Ferrite number is the normal amount) in an austenitic weld metal. Fabrications codes, e.g. ASME, will specify which electrode to use and what ferrite level it should contain. If a non-standard ferrite level is required, a special formulation can be provided by NIHONWELD in most cases.

Stainless steels are used in many applications, namely corrosion resisting, creep resisting, heat resisting, impact resisting at cryogenic temperatures, and magnetic resistance. Stainless steel electrodes can also be used to weld crack resistant joints in armour and high carbon steels. Ideally, the weld metal selected should be capable of a matching service performance to that of the base material.

Stain resistant applications are those where the corrosion rate must be virtually nil. examples can be found in the dairy, food, brewery and pharmaceutical industries, where corrosion of the smallest amount could contaminate the product. Architecture is another area where a stain free surface is required for aesthetic reasons. In these applications, electrodes which give a weld metal to match the base metal are normally used. In more agressive environment (Eg. organic acids), some care should be taken to ensure the ferrite level is compatible with the service conditions. In such cases, ferrite levels of about 5 FN are often used.

Corrosion resisting applications are those where corrosion is a factor, but the rate of corrosion has been considered in the design.

Composition of Standard Grades of Wrought Stainless and Heat-Resistant Steels (AISI, 1959)

AISI type	Nominal Composition, % C	Mn max.		Cr	Ni	Other (a)
Austenitic Steels						
201	0.15 max	7.50(b)	1.00	16.00 to 18.00	3.50 to 5.50	0.25 max N
202	0.15 max	10.50(b)	1.00	17.00 to 19.00	4.00 to 6.00	0.25 max N
301	0.15 max	2.00	1.00	16.00 to 18.00	6.00 to 8.00	.....
302	0.15 max	2.00	1.00	17.00 to 19.00	8.00 to 10.00	.....
302B	0.15 max	2.00	3.00(d)	17.00 to 19.00	8.00 to 10.00	.....
303	0.15 max	2.00	1.00	17.00 to 19.00	8.00 to 10.00	0.15 min Se
303 (Se)	0.15 max	2.00	1.00	17.00 to 19.00	8.00 to 10.00	0.15 min Se
304	0.08 max	2.00	1.00	18.00 to 20.00	8.00 to 12.00	.....
304L	0.03 max	2.00	1.00	18.00 to 20.00	8.00 to 12.00	.....
305	0.12 max	2.00	1.00	17.00 to 19.00	10.00 to 13.00	.....
308	0.08 max	2.00	1.00	19.00 to 21.00	10.00 to 12.00	.....
309	0.20 max	2.00	1.00	22.00 to 24.00	10.00 to 15.00	.....
309S	0.08 max	2.00	1.00	22.00 to 24.00	12.00 to 15.00	.....
310	0.25 max	2.00	1.50	24.00 to 26.00	19.00 to 22.00	.....
310S	0.08 max	2.00	1.50	24.00 to 26.00	19.00 to 22.00	.....
314	0.25 max	2.00	3.00(d)	23.00 to 26.00	19.00 to 22.00	.....
316	0.08 max	2.00	1.00	16.00 to 18.00	10.00 to 14.00	2.00 to 3.00 Mo
316L	0.03 max	2.00	1.00	16.00 to 18.00	19.00 to 22.00	2.00 to 3.00 Mo
317	0.08 max	2.00	1.00	18.00 to 20.00	10.00 to 14.00	2.00 to 3.00 Mo
321	0.08 max	2.00	1.00	17.00 to 19.00	9.00 to 12.00	5 x C min Ti
347	0.08 max	2.00	1.00	17.00 to 19.00	9.00 to 13.00	10 x C min Cb-Ta
348	0.08 max	2.00	1.00	17.00 to 19.00	9.00 to 13.00	10 x C min Cb-Ta 0.10 max Ta
Martensitic Steels						
403	0.15 max	1.00	0.50	11.50 to 13.00	.....	.....
410	0.15 max	1.00	1.00	11.50 to 13.50	.....	.....
414	0.15 max	1.00	1.00	11.50 to 13.50	1.25 to 2.50	.....
416	0.15 max	1.25	1.00	12.00 to 14.00	.....	0.15 min Se
416 (Se)	0.15 max	1.25	1.00	12.00 to 14.00	.....	0.15 min Se
420	0.15 min	1.00	1.00	12.00 to 14.00	.....	.....
431	0.20 max	1.00	1.00	15.00 to 17.00	1.25 to 2.50	.....
440A	0.60 to 0.75	1.00	1.00	16.00 to 18.00	.....	0.75 max Mo
440B	0.75 to 0.95	1.00	1.00	16.00 to 18.00	.....	0.75 max Mo
440C	0.95 to 1.20	1.00	1.00	16.00 to 18.00	.....	0.75 max Mo
501	0.10 min	1.00	1.00	4.00 to 6.00	.....	0.40 to 0.65 Mo
502	0.10 max	1.00	1.00	4.00 to 6.00	.....	0.40 to 0.65 Mo
Ferritic Steels						
405	0.08 max	1.00	1.00	11.50 to 14.50	.....	0.01 to 0.30 Al
430	0.12 max	1.00	1.00	14.00 to 18.00	.....	.....
430F	0.12 max	1.25	1.00	14.00 to 18.00	.....	0.15 min S
430F (Se)	0.12 max	1.25	1.00	14.00 to 18.00	.....	0.15 min Se
446	0.20 max	1.50	1.00	23.00 to 27.00	.....	0.25 max N

(a.) Other elements in addition to those shown below are as the follows: Phosphorus is 0.06% max in types 201, 202, 416, 416(Se); 430F 430F(Se), 0.045% max in types 301, 302, 302B, 304, 304L, 305, 308, 309, 309S, 310, 310S, 314,316, 316L, 317, 321 347, 348; 0.20% max in types 303 and 303 (Se). Sulfur is 0.30% max in types 201, 202, 301, 302, 302B, 304, 304L, 305, 308, 309, 309S, 310, 310S, 314, 316, 316L, 317, 321, 347, 348, 403, 405, 410, 414, 420, 430, 431, 440A, 440B, 440C, 446, 501 and 502; 0.15% min in types 303, 416 and 430F. (b.) Mn range, 5.50 to 7.50 (c.) Mn range, 7.50 to 10.00. (d.) Si range, 2.00 to 3.00. (e.) Si ranfe, 1.50 to 3.00.

The majority of chemical plants fall into this category. In application where the service temperature is below about 600°F, the low carbon grade electrodes of matching composition-not with columbium or titanium stabilized electrodes. Some environments are more agressive than the other, and the weld metal can be attacked preferentially if the wrong electrode is used. In these circumstances, care should be taken that the actual molybdenum level in the weld metal is not less than that in the parent metal, and in some cases, overalloying with molybdenum is a common practice. Ferrite level can be important also, For example, acetic acid nitric acid, and urea plant applications require a maximum of 2 FN or less to prevent corrosion.

Creep resisting applications are those where the mechanical properties of stainless steels become significant. Creep occurs at temperatures of 1000°F and above. Corrosion may not be an important factor - as with steam generating plant - or it may be significant - as with chemical and petrochemical plants operating at temperatures of 1400°F and above. At this temperatures, the use of high carbon grade electrodes ensures the maximum creep strength in the 308 or 316 categories, and they must be used to weld the high carbon grade steels. Types 347 and 321 should not be used as they can have poor ductility at these temperatures. If type 347 and 321 parent material has been used, it would be prudent to weld it with NSS-316L, NSS-317, or even NSS-308 electrode if the presence of molybdenum is detrimental. For steam plant applications the NSS-317 electrode is often used to weld type 304 plate. Ferrite levels that are very low or very high can be detrimental to the creep ductility - and the optimum range is 5-10 FN.

Heat resisting applications are those where a resistance to scaling from hot gases at temperature around 2000°F is necessary. In such applications there is a greater use of types 309, 310, 446 and higher alloyed metals. Matching electrodes are normally used with the exception of E347 and ER321 as stated earlier, and molybdenum bearing weld metal in oxidizing environments. Stainless steel casting used for these high temperature application are designated the H grades by ACI. Examples are the HK and HT grades and these must be welded with electrodes that deposit about .40% carbon, i.e. NSS-310 and NSS-410 electrodes respectively.

Impact resisting applications are normally those at the cryogenic temperatures of liquid nitrogen/oxygen or even liquid helium. Here corrosion is not a problem and non-matching electrodes are acceptable provided they give good mechanical properties with a crack free joint. Normally impact toughness as measured by the Charpy V-notch test is the criteria. It has been shown that carbon, nitrogen and ferrite are detrimental to toughness. Therefore, an NSS-316L with 2 FN max. and maximum nitrogen content is a usual choice, even for a welding of type 304. NSS-316 gives a more crack resistant deposit than NSS-308 L and so does a - 15 coating compared to a - 16 coating.

Non-magnetic steel is often required in electrical generation equipment, super-conducting installations (which may also required cryogenic properties) and mine sweepers. The magnetic permeability, mp, is the measure of the ability of a material to be affected by magnetic fields. A figure of 1.00 is fully non-magnetic and 1.10 max. is often specified for weld metal to be used in this non-magnetic applications. Corrosion resistance is generally not required. Fully austenitic stainless steel are non-magnetic, but even the standard levels of ferrite found in many austenitic weld metals gives a magnetic permeability greater than 1.10. Which electrode to use is usually governed by the fabrication standards and is often NSS-308, NSS-310 or NSS-316L with a 2 FN maximum. The low ferrite can cause cracking problems and this should be considered when choosing the electrode, with E316L-15 pro-bably the most crack resistant.

The welding of low alloy steel to stainless steel is also an area where service conditions and postweld heat treatments should be considered when choosing an electrode. Normally, one of the high ferrite NSS-309 series of electrodes, NSS-312 or an NSS-307 electrode should be chosen. Here, the high alloy and ferrite contents are diluted by the low alloy steel and ideally give a weld metal of 5-10 FN. Consultation of the Schaeffler diagram to predict the weld metal ferrite content can be helpful. If the service temperature is to be above 600°F or below-75°F, or if a postweld heat treatment is contemplated, a high nickel electrode such as NSS-310Cb or NSS-30 Mo should be used. Where high dilution may occur or a high carbon low alloy steel is to be welded, a NSS-312 electrode with the highest ferrite content is often the answer. The NSS-307 and NSS-308L electrodes are designed to weld high carbon steels such as armor plate.

The surfacing of low alloy steels for corrosion resistance is usually accomplished by the appropriate NSS-309 electrode to overcome the dilution of the base material. Then a second and even a third layer of the required analysis is welded on top. If the application requires wear and impact resistance, NHF-33CRS or NHF-30CRS electrodes should be considered.

One example of the effect of service on the choice of a welding electrode can be seen with the martensitic type 410 steels. These steels can be used for high temperature creep, corrosion or even wear resisting or used for resistance to stress corrosion cracking with low temperature mechanical property requirements. High carbon levels are best suited to the latter. Unless special requirements apply, the standard NSS-410 electrodes are normally suitable. These 410 steels require pre-heating and post weld heat treating. If the service environment of the weld would allow reduced corrosion resistance and mechanical properties, these steels can be welded with NSS-309 or NSS-310 electrodes without preheat or post weld heat treatment, ideal for field erection where heat treating can be a problem.

NIHONWELD electrode selector guide for Stainless Steels

AISI TYPE NUMBER	442 446	430F 430FSE	430 431	501 502	416 416SE	403 405 410 420 414	321 348 347	317	316L	316	314	310 310S	309 309S	304L	303 303SE	201 202 301 302 302B 304 305 308	MILD STEEL
201-202-301 302-302B-304 305-308	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**309** 310 312	**309** 310 312	**308**	**308**	**308**	**308**	**308**	**308**	**308**	**308**	**308**	**308**	**312** 310 309
303 303SE	**310** 309 312	**310** 309 312	**310** 309 310	**310** 309 310	**309** 310 312	**309** 310 312	**308**	**308**	**308**	**308**	**308**	**308**	**308**	**308**	**308-15**	**308**	**312** 310 309
304L	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309** 310 312	**309** 310 312	**308**	**308**	**308-L**	**308**	**308**	**308**	**308**	**308-L**	**308**	**308**	**312** 310 309
309 309S	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309** 310 312	**309** 310 312	**308**	**317** 316 309	**316**	**316**	**310**	**310**	**309** 310	**308**	**308**	**308**	**310** 309 312
310 310S	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309**	**317** 316 309	**309** 310 312	**309** 310 312	**310-15** 312	**310** 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**310** 309 312
314	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 309 312	**309** 310 308	**309** 310	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309	**310** 312 309
316	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309** 310 312	**309** 310 312	**308**	**316**	**316**	**316**	**309** 310 316	**310** 309 316	**309** 310 316	**308** 316	**308** 316	**308** 316	**309** 310 312
316L	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 310 312	**309** 310 312	**308**	**316L**	**316**	**309** 310 316	**310** 309 316	**316** 309	**308** 316	**308** 316	**308** 316	**308** 316	**310** 309 312
317	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309** 310 312	**309** 310 312	**308**	**317**	**316** 308	**316** 308	**317** 316 309	**317** 316 309	**317** 316 309	**308** 316 317	**308** 316 317	**308** 316 317	**309** 310 312
321 348 347	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309** 310 312	**309** 310 312		**308** 347	**347** 308	**347** 308	**309** 310 347	**347** 308	**347** 308	**347** 308-L	**347** 308	**347** 308	**309** 310 312
403-405 410-420 414	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**309** 310	**410◊** 309◊◊	**309** 310	**309** 310	**309** 310	**309** 310	**309** 310	**309** 310	**309** 310	**309** 310	**309** 310	**309** 310	**310** 309 312
416 416SE	**310** 309	**310** 309	**310** 309	**310**	**410-15◊**	**410-15◊** 309◊◊ 310◊◊	**309** 310	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312	**309** 310 312
501 502	**310**	**310**	**310**	**502◊** 310◊◊	**310**	**310**	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 312 309
430 431	**310** 309	**310** 309	**430-15◊** 310◊◊ 309◊◊	**310**	**310**	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309	**310** 309 312
430F 430SE	**310** 309	410-15◊	**310** 309	**310** 309	**310** 309 312	**310** 309 312	**309** 310 312	**319** 319 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312
442 446	**309** 310	**309** 310 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312	**310** 309 312

Use of Chart

Pick AISI ALLOY NUMBER on left side, read accross till you match it with same number at top. EXAMPLE: 304L to 304L. The NIHONWELD Electrode to use is NSS 308L. If you are going to weld 304L to 316L the NIHONWELD Electrode to use would be NSS308L, If choice is 304L to mild steel you would have three (3) choice NSS 312, NSS 310, NSS 309. Also add prefix NSS to the electrode number to get NIHONWELD Electrode.

(FOOTNOTE)

◊ Preheat
◊◊ No Preheat Necessary
Bold numbers indicate first choice,light numbers indicate second and third choice. This choice ca vary with specific applications and individual job requirements

CHART 2. Pre- Heat & Post-Heat Treatment Chart

Recommended heat treatments to obtain optimum performance from welded wrought 300 and 400 Series Stainless Grades.

A.I.S.I. Type	Weld Pre-Heat	Post-Weld-Heat Treatment
301 302	(a) (a)	Cool rapidly from 1950/2100°F if corrosion conditions moderate to severe
304	(a)	Cool rapidly from 1900/2000°F only when corrosion conditons severe
304L	(a)	Not required for corrosion purposes.
309 310 (c)	(a) (a)	Usually unnecessary because grades generally used for high temperature service.
316	(a)	Cool rapidly from 1950/2100°F when corrosion conditions severe.
316L	(a)	Not required for corrosion purposes.
321 347 348	(a) (a) (a)	Not required for corrosion purposes.
403 410 405 430	400/600°F (d) 400/600°F (d) 400/600°F (d) 400/600°F (d)	Air cool from 1200/1400°F
434 442 445	400/600°F (d) 400/600°F (d) 400/600°F (d)	Air cool from 1400/1450°F Air cool from 1450/1550°F Cool rapidly from 1500/1550°F

(a) Unnecessary when the steel is above 50°F
(b) 0.40 carbon percentage maximum
(c) When corrosion is a factor 309S and 310S are used The post weld treatment is cool rapidly from between 2050°F / 2150°F.
(d) Light guage stainless sheet is frequently welded without preheating.
(e) May be welded with 308, 309 or 310 electrodes without preheating if steel is above 50°F.

SUPPLEMENTARY CONVERSION TABLES

Temperature Conversion Table

°F	°C	°F	°C	°F	°C	°F	°C	°F	°C
-400	-240	20	-6.7	120	48.9	220	104.4	940	504.4
-390	-234	22	-5.6	122	50.0	230	110.0	960	515.6
-380	-229	24	-4.4	124	51.1	240	115.6	980	527
-370	-223	26	-3.3	126	52.2	250	121.1	1000	538
-360	-218	28	-2.2	128	53.3	260	126.7	1020	549
-350	-212	30	-1.1	130	54.4	270	132.2	1040	560
-340	-207	32	0	132	55.6	280	137.8	1060	571
-330	-201	34	1.1	134	7	290	143.3	1080	582
-320	-196	36	2.2	136	8	300	148.9	1100	593
-310	-190	38	3.3	138	58.9	310	154.4	1200	604
-300	-184	40	4.4	140	60.0	320	160.0	1140	616
-290	-179	42	5.6	142	61.1	330	165.6	1160	627
-280	-173	44	6.7	144	62.2	340	171.1	1180	638
-270	-168	46	7.8	146	63.3	350	176.7	1200	649
-260	-162	48	8.9	148	64.4	360	182.2	1220	660
-250	-157	50	10.0	150	65.6	370	187.8	1240	671
-240	-151	52	11.1	152	66.7	380	193.3	1260	682
-230	-146	54	12.2	154	67.8	390	198.9	1280	693
-220	-140	56	13.3	156	68.9	400	204.4	1300	704
-210	-134	58	14.4	158	70.0	410	210.0	1320	716
-200	-129	60	15.6	160	71.1	420	215.6	1340	727
-190	-123	62	16.7	162	72.2	430	221.1	1360	738
-180	-118	64	17.8	164	73.3	440	226.7	1380	749
-170	-112	66	18.9	166	74.4	450	232.2	1400	760
-160	-107	68	20.0	168	75.6	460	237.8	1420	771
-150	-101	70	21.1	170	76.7	470	243.3	1440	782
-140	-96	72	22.2	172	77.8	480	248.9	1460	793
-130	-90	74	23.2	174	78.9	490	254.4	1480	804
-120	-84	76	24.4	176	80.0	500	260.0	1500	816
-110	-79	78	25.6	178	81.1	520	271.1	1520	827
-100	-73	80	26.7	180	82.2	540	282.2	1540	838
-90	-68	82	27.8	182	83.3	560	293.3	1560	849
-80	-62	84	27.8	184	84.4	580	304.4	1580	860
-70	-57	86	30.0	186	85.6	600	315.6	1600	871
-60	-51	88	31.1	188	86.7	620	326.7	1620	882
-50	-45.6	90	32.2	190	87.8	640	337.8	1640	893
-40	-40.0	92	33.3	192	88.9	660	348.9	1660	904
-30	-34.4	94	34.4	194	90.9	680	360.0	1680	916
-20	-28.9	96	35.6	196	91.1	700	371.1	1700	927
-10	-23.3	98	36.7	198	92.2	720	382.2	1720	938
0	-17.8	100	37.8	200	93.3	740	393.3	1740	949
2	-16.7	102	38.9	202	94.4	760	404.4	1760	960
4	-15.6	104	40.0	204	95.6	780	415.6	1780	971
6	-14.4	106	41.1	206	96.7	800	426.7	1800	982
8	-13.3	108	42.2	208	97.8	820	437.8	1820	993
10	-12.2	110	43.3	210	98.9	840	448.9	1840	1004
12	-11.1	112	44.4	212	100.0	860	460.0	1860	1016
14	-10.0	114	44.4	214	101.1	880	471.1	1880	1027
16	-8.9	116	46.7	216	102.2	900	482.2	1900	1038
18	-7.8	118	47.8	218	103.3	920	493.3	1920	1049

Length Conversion Table

in.	mil.	mm	in.	mil.	mm
1/64	15.625	0.39688	33/64	515.63	13.097
1/32	31.250	0.79375	17/32	531.25	13.494
3/64	46.875	1.1906	35/64	546.88	13.891
1/16	62.500	1.5875	9/16	562.50	14.288
5/64	78.125	1.9844	37/64	578.13	14.684
3/32	93.750	2.3813	19/32	593.75	15.081
7/64	109.38	2.7781	39/64	609.38	15.478
1/8	125.00	3.1750	5/8	625.00	15.875
9/64	140.63	3.5179	41/64	640.63	16.272
5/32	156.25	3.9688	21/32	656.25	16.272
11/64	171.88	4.3656	43/64	671.88	17.066
3/16	187.50	4.7625	11/16	687.50	17.463
13/64	140.63	3.5719	45/64	703.13	17.859
7/32	218.75	5.5563	23/32	718.75	18.256
15/64	234.38	5.9531	47/64	734.38	18.653
1/4	250.00	6.3500	3/4	750.00	19.050
17/64	265.63	6.7469	49/64	765.63	19.447
9/32	281.25	7.1438	25/32	781.25	19.844
19/64	296.88	7.5406	51/64	796.88	20.241
5/16	312.50	7.9375	13/16	812.50	20.638
21/64	328.13	8.3344	53/64	828.13	21.034
11/32	343.75	8.7313	27/32	843.76	21.431
23/64	359.38	9.1281	55/64	859.38	21.823
3/8	375.00	9.5250	7/8	875.00	22.225
25/64	390.63	9.9212	57/64	890.63	22.622
13/32	406.25	10.319	29/32	906.25	23.019
27/64	421.88	10.716	59/64	921.88	23.416
7/16	437.50	11.113	15/16	937.50	23.813
29/64	453.13	11.509	61/64	953.13	24.209
15/32	468.75	11.906	31/32	968.75	24.003
31/64	484.38	12.303	63/64	984.38	25.003
1/2	500.00	12.700	1	1000.00	25.400

(Ft * 1bs- kg * m)

Stress Conversion Table

1bs/in²	0,000	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000
0,000	0.000	0.703	1.406	2.109	2.812	3.515	4.218	4.291	5.625	6.328
10,000	7.031	7.734	8.437	9.140	9.843	10.546	11.249	11.952	12.655	13.358
20,000	14.061	14.764	15.468	16.171	16.874	17.577	18.280	18.983	19.686	20.389
30,000	21.092	21.795	22.498	23.201	23.904	24.607	25.311	26.014	26.717	27.420
40,000	28.123	28.826	29.529	30.232	30.935	31.638	32.341	33.044	33.747	34.450
50,000	35.154	35.857	36.560	37.263	37.966	38.669	39.372	40.075	40.778	41.481
60,000	42.184	42.887	43.590	44.293	44.996	45.700	46.403	47.106	47.809	48.512
70,000	49.215	49.918	50.621	51.324	52.027	52.730	53.433	54.136	54.839	55.543
80,000	63.276	63.979	64.682	65.386	66.089	66.792	67.495	68.198	68.901	69.604
90,000	63.276	63.979	64.682	65.386	66.089	66.792	67.495	68.198	68.901	69.604
100,000	70.307	71.010	71.713	72.416	73.119	73.822	74.525	75.228	75.932	76.635
110,000	77.368	78.041	78.744	79.447	80.150	80.853	81.556	82.259	82.962	83.665
120,000	84.368	85.071	85.774	86.478	87.181	87.884	88.587	89.290	89.993	90.696
130,000	91.399	92.102	92.805	93.508	94.211	94.914	95.618	96.321	97.024	97.727
140,000	98.460	99.133	99.836	100.539	101.242	101.945	102.648	103.351	104.054	104.757
150,000	105.460	106.164	106.867	107.570	108.273	108.976	109.679	110.382	111.085	111.788
160,000	112.491	113.194	113.897	114.600	115.303	116.007	116.710	117.413	118.116	118.819
170,000	119.522	120.225	120.928	121.631	122.334	123.037	123.740	124.443	125.146	125.850
180,000	126.553	127.256	127.959	128.662	129.365	130.771	131.474	132.177	132.88	132.880
190,000	133.583	134.286	134.989	135.693	136.396	137.099	137.802	138.505	139.208	139.911
200,000	140.614	141.317	142.020	142.723	143.426	144.426	144.129	144.832	145.535	146.942
210,000	147.645	148.348	149.051	149.754	150.457	151.160	151.863	152.566	153.269	153.972
220,000	154.675	155.378	156.082	156.785	157.488	158.191	158.894	159.597	160.300	161.003
230,000	161.706	162.409	163.112	163.815	164.518	165.221	165.925	166.628	167.331	168.034
240,000	168.737	169.440	170.143	170.846	171.549	172.252	172.955	173.658	174.361	175.064
250,000	175.768	176.471	177.174	177.877	178.580	179.283	179.986	180.689	181.932	182.095

1 bs/in²	100	200	300	400	500	600	700	800	900
kg/mm²	0.0703	0.1406	0.2106	0.3515	0.2812	0.4218	0.4921	0.5625	0.6328

1 1bs/in² = 0.000703070 kg/mm²

Hardness Conversion Table

Vickers Hardness Hv	Brinell Hardness 10m Ball 3000kg Load		Rockwell Hardness		Shore Hardness (Hs)	Tensile Strength (kg/mm) (approx.)
	Standard Ball	Tungsten carbide Ball	B seale (HRB)	C scale (HRC)		
940	-	-	-	68.0	97	-
920	-	-	-	67.5	96	-
900	-	767	-	67.0	95	-
880	-	757	-	66.4	93	-
860	-	757	-	65.9	92	-
840	-	745	-	65.3	91	-
820	-	733	-	64.7	90	-
800	-	722	-	64.0	88	-
780	710	710	-	63.5	87	-
760	-	698	-	62.6	86	-
740	-	684	-	61.8	84	-
720	-	670	-	61.0	83	-
700	-	656	-	60.1	81	-
690	-	647	-	59.7	-	-
680	-	638	-	59.2	80	-
470	-	630	-	58.8	-	227
660	-	620	-	58.3	79	224
650	-	611	-	57.8	-	220
640	-	601	-	57.3	77	217
630	-	591	-	56.8	-	213
620	-	582	-	56.3	75	210
610	-	573	-	55.7	-	206
600	-	564	-	55.2	74	203
590	-	554	-	54.7	-	199
580	-	545	-	54.1	72	196
570	-	535	-	53.6	-	192
560	-	525	-	53.0	71	189
550	505	517	-	52.3	-	185
540	496	507	-	51.7	69	182
530	488	497	-	51.1	-	178
520	480	488	-	50.5	67	175
510	473	479	-	49.8	-	171
500	465	471	-	49.1	66	168
490	456	460	-	48.4	-	164
480	448	452	-	47.7	64	161
470	441	442	-	46.9	-	157
460	433	433	-	46.1	62	154
450	425	425	-	45.3	-	150
440	415	415	-	44.5	59	147
430	405	405	-	43.6	-	143
420	397	397	-	42.7	57	140
410	388	388	-	41.8	-	137
400	379	379	-	41.8	55	133
390	369	369	-	40.8	-	130
380	360	360	(110.0)	38.8	52	126
370	350	350	-	37.7	-	123
360	341	341	(109.0)	36.5	50	119
350	331	331	-	35.5	-	116
340	322	322	(108.0)	34.4	47	113
330	313	313	-	33.3	-	109
320	303	303	(107.0)	32.2	45	106
310	294	294	-	31.0	-	102
300	284	284	(105.5)	29.8	42	99
295	280	284	-	29.2	-	97.8
290	275	275	(104.5)	28.5	41	95.2
285	270	270	-	27.8	-	94.1
280	265	266	(103.5)	27.1	40	92.0
275	261	261	-	26.4	-	90.6
270	256	256	(102.0)	25.6	38	88.6
265	252	252	-	24.8	-	87.2
260	247	248	(101.0)	24.0	37	85.1

Impact Value Conversion Table

ft •1bs	0	1	2	3	4	5	6	7	8	9	ft •1bs
ft •1bs	kg • m	kg • m	kg • m	kg • m	kg • m	kg • m	kg • m	kg • m	kg • m	kg • m	
0	0.000	0.138	0.277	0.415	0.553	0.691	0.830	0.968	1.106	1.106	0
10	1.383	1521	1.659	1.789	1.936	2.074	2.212	2.350	2.489	2.489	10
20	2.765	2.903	3.042	3.180	3.318	3.456	3.595	3.733	3.871	3.871	20
30	4.148	4.286	4.424	4.562	4.701	4.839	4.977	5.116	5.254	5.254	30
40	5.530	5.669	5.807	5.945	6.083	6.222	6.360	6.498	6.636	6.636	40
50	6.913	7.051	7.189	7.328	7.466	7.604	7.742	7.881	8.019	8.019	50
60	8.295	8.434	8.572	8.710	8.848	8.987	9.125	9.263	9.401	9.401	60
70	9.678	9.816	9.955	10.093	10.231	10.369	10.508	10.646	10.784	10.784	70
80	11.061	11.199	11.337	11.475	11.614	11.752	11.890	12.028	12.167	12.167	80
90	12.443	12.581	12.720	12.858	12.996	13.134	13.273	13.411	13.549	13.549	90
100	13.826	13.964	14.102	14.240	14.379	14.517	14.655	14.794	14.932	14.932	100
110	15.208	15.347	15.485	15.623	15.761	15.900	16.038	16.176	16.314	16.314	110
120	16.591	16.729	16.867	17.006	17.144	17.282	17.420	17.559	17.697	17.697	120

ft •1bs = 0.13825728 kg• m

Glossary to Welding Terms

Abrasion - the wearing away of a surface by repeated friction with a harder substance.

Air Hardening Steel - a steel containing sufficient carbon and other alloying elements to harden fully during cooling in air or other gaseous mediums from a temperature above its transformation range.

Alloy Steel - steel containing significant quantities of alloying elements (other than carbon and the commonly accepted amounts of manganese, silicon sulfur, and phosphorus) added to effect changes in the mechanical and physical properties.

Annealing - healing to and holding at a suitable rate, for such purposes as reducing hardness improving machineability, facilitating cold working, producing a desired microstructure or obtaining desired mechanical, physical or other properties.

Arc Blow - magnetic disturbance of the arc (when welding wiyh Dc current) which causes it to waver from its intended paths.

Arc Length - the distance from the tip o f the core wire or rod to the point where the arc makes contact with the work surface.

Austenitic Steel - an alloy steel which structure is normally austenitic at room temperature.

Austenitizing - forming austenitic by heating a ferrous alloy into the transformation range (complete austenizing)

Benite - a decompositon product of austenitic consisting of an aggregate of ferrite and carbide.

Base or Parent Meta l- the metal to be welded or surfaced.

Bead - a layer of weld metal passage of electrodes or rod.

Blow Holes- small and pinlike holes found on the weld metal usually by the trapped gases moisture during welding.

Brazing - joining together of metals of a filler metal with a lower melting point than the base metal. Coalescence is produced by the diffusion of the molten filler metal into the surface of the base metal at a temperature lower than the melting point of the latter (about 450 - 800°C).

Brinell Hardness Test - a test for determining the hardness of a material by forcing a hard steel or carbide ball of specified diameter into it under a specified load.

Brittleness - the quality of the material that leads to crack propogation without appreciable plastic depormation.

Buttering - depositing weld metal on the face of the point to increase weld ability.

Carbide - a compound of carbon with one or more metallic elements.

Carbon Steel - steel containing carbon up to 2% and only redual quantities of other elements except those added for deoxidation, with silicon usually limited to 0.60% and manganese to about 1.65%. Also termed plain carbon steel, ordinarili steel, and straight carbon steel.

Carburizing - introducing carbon into a solid ferrous alloy by holding above the AC, in contact with a suitable carbonaceous material.

Case Hardening - hardening a ferrous alloy so that the outer portion, or case, is made substantially harder than the inner portion, or core.

Charpy Test - a pendulum type single blow impact test in which the specimen, usually notched, is supported at both ends as simple beams and broken by a falling pendulum. The energy absorbed, as determined by the subsequent rise of the pendulum is a measured of impact strength for notched toughness.

Critical Point - the temperature of pressure at which a change in crystal structure, phase of physical properties occurs, Same as transformation temperature.

Crystal - a solid composed of atoms, ions, or molecules arranged in a pattern which is repitative in three dimensions.

Cold - (or Unbeaded) Cracking- cracking in the base metal just below the fusion zone, associated with the presence of hydrogen in the arc speciaaly in welding high carbon and higher sulfur steels; occurs after weldment has cooled to room temperature.Surface of a cold crack is bright and clean while that of a hot crack is discolored.

Corrosion - wearing away of a material by chemical attack (mainly oxidation).

Deposition Efficiency - the ratio of the weight of the weld deposit to the weight of the core wire consumed, usuaaly expressed in %. Except for iron powder types (and those electrodes with high content of ferro-alloys in the coating). this value is always less than 100 because of the loss of metal by spattering, violation of metal at the arc and reaction with the slag constituents.

Deposition (or melt-down) - Rate the speed of deposition of the filler metal expressed as weigth rod consumed per unit time per ampere.

Dilatometer - an instruments for measuring expansion or contraction in a metal resulting from changes in such as temperature or allotropy.

Dragging - welding in which the electrode coating touches the surface of the base metal and movement is along straight and steady line in one direction.

Elongation in 2” - in tensile strength testing, the percentage increase in length of a 2-inch portion of the test piece at the break-point; an indication of the ductility of the metal sample.

Etching - subjecting the surface of the metal to preferential to chemical or electrolytic attack in order to reveal structural details.

Filler Weld - a weld joining two surfaces approximately at right angles to each other.

Fibrous Structure - a columnar structure present in moistured part of weld metal, arises when the properties of weld metal are inform (rich in C, P, S) and the cooling rate of weld metal is too fast.

Fish Eyes - silver grayish eyelike appearance in which appear in the fracture parts of weld metals produced when moisture absorbed electrodes are used and cooling rate is too fast.

Galling - developing a condition on the rubbing surface of one or both mating parts where excessive friction between high spots results in localized welding with subsequent spalling and a further roughening of the surface.

Grain - an individual crystal and a polycrystalline metal or alloy.

Hot-Cracking - occurs in a bead during welding (at above 850°C) usually located in the last to-freeze metal after the arc has passed. Sulfur and Phosphorus are the principal culprits for this type of cracking.

Impact Value - the minimum value, in work or energy units/unit cross-section, of the energy required to break a nickel sample by a sharp blow under specified conditions of temperature, speed of force, size and shape of the nick and specimen. The Charpy-V-notch value is given in ft., lbs., the cross-section of the specimen being 0.8 cm. x 0.8 cm. and the speed of force 5 meters per second. This value is the measure of the brittleness or toughness of the sample.

Interface - a surface which forms the boundary between phases or systems.

Interpass Temperature - in a multi-pass weld, the lowest temperature of a pass before the succeeding one is commenced.

Macroscopic - visible at magnifications from 1 to 10 diameters.

Matrix - the principal phase or aggregate in which another constituent is embedded.

Microstructure - a structure of a polished and etched metal as revealed by a microscope at a magnification greater than ten diameters.

Overlap - protrusion of the weld metal above the base metal beyond the limits of fusion.

Peening - mechanical working of a metal under the blows of a hammer to induce plastic flow and relieve shrinkage stresses by the lateral expansion of metal.

Penetration of Depth of Fusion - the distance from the original surface of the base metal to the point where fusion ceases.

Porosity - the presence of fine pores or pinholes inside the weld due to entrapped gases.

Post-Heating - heat treatment after welding employed for the same reason as pre-heating.

Pre-Heating - heating work piece to specified temperatures before welding to reduce rate of cooling of the weld and decrease shrinkage stresses. Reducing the cooling rate prevents the formation of hardened brittle zones which fracture readily.

Sceleroscope Test - a hardness test where the loss in kinetic energy of a falling metal absorbed by the indentation upon impact on the metal being tested, is indicated by the height of rebound. Also called Shore Hardness Test.

Slag - the non-metallic or mineral constituents of the coating which have melted and fused at the temperatured of the arc and solidified over the weld bead.

Slag Inclusion - portions of the slag entrapped wuth in the weld metal usually caused by too low current, too short arc or insufficient puddling time.

Soldering - brazing at temperatures less than 450°C.

Spalling -the cracking and flaking of particles out of a surface.

Spatter - the metal particles expelled during welding which do not form part of the bead.

Tack Weld - a generally short weld made to hold parts of a weld ment in place until final weld are made. Used for assembly purpose only.

Tempering - pre-heating a quench-hardened or normalized ferrous alloy to a temperature below the transformation range and then cooling at a rate desired.

Tensile Strength - (T.S.)- the maximum forces/unit cross-section attained when specimen is pulled till break point.

Transformation Temperature - the temperature at which a change in phase occurs.

Undercut - grooved melted into the base metal along side or sides of weld bead and left unfilled.

Weaving - welding technique in which electrode is made to oscillate from side to side.

Welding - joining of metals involving melting and fusions of the surface to be joined with or without a filler metal.

Weld Deposit - metal coming from the filler rod or electrode.

Weld Metal - the weld deposit plus the portion of the base metal fused with it

Whipping - welding technique in which electrode is made to oscillate in the direction of travel.

Work-Hardening - an increase in hardness and strength caused by plastic deformation and temperature lower than the recrystallization range. Also called Strain Hardening.

X-Ray Quality - when X-ray pictures of weld psses comparison with accepted standards with respect to comparison toporosity and or other defects.

Yeild Point (Y.P.) - the minimum force/unit cross-section required to bring a-bout permanent deformation.

COVERED ARC WELDING ELECTRODES FOR SHIELDED METAL ARC WELDING (SMAW) FOR STAINLESS STEEL

Type of Coating	Brand Name	Equivalent Specifications AWS (JIS)	Type of Current	Typical All Weld Deposit Analysis (%)							Typical All Weld Mechanical Properties		Applications
				C	SI	Mn	Cr	Ni	Mo	Others	T.S. N/mm² (Ksi)	Elongation (%)	
LOW HYDROGEN TYPE	NSS-308L-15	E308L-15 (D308L-15)	DC (+)	0.03	0.41	1.20	20.60	9.50	-	-	550 (80)	44	Basic electrode for welding of low carbon 18% Cr - 8% Ni Stainless Steel.
	NSS-316L-15	E316L-15 (D316L-15)	DC (+)	0.03	0.40	1.21	19.20	11.40	2.30	-	590 (86)	39	Basic electrode for welding of low carbon 18% Cr - 12% Ni - Mo steel (AISI Types 316, 316L)
	NSS-309L-15	E309L-15 (D309L-15)	DC (+)	0.03	0.40	1.32	24.30	13.20	-	-	590 (386)	38	Basic electrode for welding of low carbon 22% Cr - 12% Ni steel, carbon steel or low alloy steel to stainless steel & stainless clad steel.
LIME TITANIA TYPE	NSS-307	E307-16 (D307-16)	AC DC (+)	0.06	0.68	5.66	19.87	9.73	0.98	-	640 (93)	45	Welding dissimilar steel such as welding austenitic manganese steel to carbon steel forgings or castings.
	NSS-308	E308-16 (D308-16)	AC DC (+)	0.05	0.66	1.00	20.00	10.50	-	-	590 (86)	40	For welding of 18% Cr - 8% Ni steel such as AISI Types 301, 302, 304, 305 and 308.
	NSW-308	E308-16 (D308-16)	AC DC (+)	0.06	0.45	1.86	20.03	9.75	-	-	593 (86)	46	For welding of 18% Cr - 8% Ni steel such as AISI Types 301, 302, 304, 305 and 308.
	NSS-308L (ABS)	E308L-16 (D308L-16)	AC DC (+)	0.02	0.67	1.03	19.97	9.69	-	-	590 (86)	45	For welding of 18% Cr - 8% Ni steel such as AISI Types 301, 302, 304, 305 and 308.
	NSW-308L (ABS)	E308L-16 (D308L-16)	AC DC (+)	0.02	0.40	1.85	19.59	10.35	-	-	567 (82)	47	For welding low carbon 18% Cr - 8% Ni steel.
	NSS-309L (ABS)	E309L-16 (D309L-16)	AC DC (+)	0.03	0.69	0.97	24.02	13.21	-	-	558 (81)	44	For welding low carbon 22% Cr - 12% Ni Steel, carbon steel or low alloy steel to stainless steel & stainless clad steel.
	NSW-309L (ABS)	E309L-16 (D309L-16)	AC DC (+)	0.03	0.36	1.80	23.83	12.57	-	-	606 (88)	41	For welding low carbon 22% Cr - 12% Ni Steel, carbon steel or low alloy steel to stainless steel & stainless clad steel.
	NSS-309 MoL	E309MoL-16 (D309MoL-16)	AC DC (+)	0.03	0.65	1.10	23.71	12.84	2.31	-	606 (88)	41	For welding of Type 316 clad steel or dissimilar steel. Corrosion resistant lining of carbon steels or low alloy steel.
	NSS-310	E310-16 (D310-16)	AC DC (+)	0.10	0.41	2.19	25.98	20.75	-	-	581 (84)	41	For welding of 25% Cr - 20% Ni Steel and clad side of 18% Cr - 8% Ni clad steel. Perfect austenitic microstructure.
	NSS-310Mo	E310Mo-16 (D310Mo-16)	AC DC (+)	0.09	0.44	2.25	25.92	20.68	2.26	-	621 (90)	35	For welding of 25% Cr - 20% Ni - 2% Mo Steel. Excellent corrosion resistance to sulfuric acid and good resistability to cracking and higher tensile strength at high temperature.
	NSS-312	E312-16 (D312-16)	AC DC (+)	0.09	0.67	1.62	28.75	9.39	-	-	761 (110)	24	For welding of 29% Cr - 9% Ni type cast steel. Joint welding difficult-to-weld steel. For a swear resistant build up and buffer layer for hardfacing.
	NSS-303	E312-16 (D312-16)	AC DC (+)	0.09	0.65	1.58	28.62	9.40	-	-	763 (111)	26	For welding of 29% Cr - 9% Ni type cast steel. Joint welding difficult-to-weld steel. For a swear resistant build up and buffer layer for hardfacing.
	NSS-316	E316-16 (D316-16)	AC DC (+)	0.06	0.66	1.78	19.33	12.31	2.26	-	590 (86)	44	For welding of 18% Cr - 12% Ni - Mo steel (AISI Types 316). Underlying of the build up welding of 13% Mn steel.
	NSS-316L (ABS)	E316L-16 (D316L-16)	AC DC (+)	0.02	0.68	1.67	19.12	12.25	2.27	-	567 (82)	45	For welding low carbon, molybdenum-bearing austenitic alloys. Welding of 18% Cr - 12% Ni - 2% Mo steel where the corrosion resistant qualities are required.
	NSW-316L (ABS)	E316L-16 (D316L-16)	AC DC (+)	0.02	0.38	1.58	19.27	12.27	2.23	-	540 (55)	47	For welding low carbon, molybdenum-bearing austenitic alloys. Welding of 18% Cr - 12% Ni - 2% Mo steel where the corrosion resistant qualities are required.
	NSS-317L	E317L-16 (D317L-16)	AC DC (+)	0.02	0.69	1.68	19.18	12.65	3.32	-	584 (85)	42	For welding AISI Types 317, 317L.
	NSS-318	E318-16	AC DC (+)	0.06	0.67	1.76	19.07	12.66	2.24	Nb & Ta 0.65	612 (89)	35	PS-318 is similar to PS-316 but contains niobium (Nb) to provide resistance to intergranular carbide precipitation.

COVERED ARC WELDING ELECTRODES FOR SHIELDED METAL ARC WELDING (SMAW) FOR STAINLESS STEEL

Type of Coating	Brand Name	Equivalent Specifications AWS (JIS)	Type of Current	Typical All Weld Deposit Analysis (%)							Typical All Weld Mechanical Properties		Applications
				C	Si	Mn	Cr	Ni	Mo	Others	T.S. N/mm² (Ksi)	Elongation (%)	
LIME TITANIA TYPE	NSS-320	E320-16	AC DC (+)	0.05	0.40	2.02	20.09	34.54	2.34	Nb & Ta 0.68	582 (84)	39	For welding alloys if similar composition in wrought & cast forms. Provides very good corrosion resistance to a wide range of chemical environments.
	NSS-330	E330-16	AC DC (+)	0.20	0.35	2.15	16.42	35.24	-	-	537 (78)	34	For excellent resistance to oxidation, curburization & thermal cycling shock at high temparature.
	NSS-347	E347-16 (D347-16)	AC DC (+)	0.05	0.44	1.73	19.93	10.06	-	Nb & Ta 0.68	638 (93)	39	For welding of 18% Cr - 8% Ni - Cb steel (AISI Type 321) and low carbon 18% Cr - 8% Ni steel (AISI Type 304L)
	NSS-347L	E347L-16 (D347L-16)	AC DC (+)	0.03	0.57	1.74	19.27	10.40	0.05	Nb & Ta 0.62	589 (84)	44	For welding low carbon 18% Cr - 8% Ni - Cb steel more resistant to intergranular corrosion than PHILSTAIN 347.
	NSS-410	E410-16 (D410-16)	AC DC (+)	0.08	0.38	0.46	12.80	0.10	-	-	515 (75)	32	For welding of 13% Cr steel. Surfacing of carbon steel to resist corrosion, erosion or abrasion.
	NSS-410 NiMo	E410NiMo-16	AC DC (+)	0.043	0.27	0.33	12.18	4.52	0.068	-	600°C x 5 hr 917 (133)	18	For welding of 13%cCr steel. Surfacing of carbon steel to resist heat, corrosion, erosion and abrasion.
	NSS-430	E430-16 (D430-16)	AC DC (+)	0.06	0.35	0.47	17.30	-	-	-	546 (79)	27	For welding 17% Cr stainless steel. Welding of clad side of stainless clad steel (AISI Types 403, 405) to resist corrosion, erosion.
	NSS-430Nb	(D430Nb-16)	AC DC (+)	0.05	0.32	0.40	17.39	0.007	0.21	Nb&Ta 0.86	310 (45)	31	For welding 17% Cr stainless steel. Tensile strength at high temperature is very high and the resistability for interangular corrosion is excellent.
	NSS-502	E502-16 (DT2516)	AC DC (+)	0.06	0.43	0.57	4.98	-	0.51	-	420 (61)	540 (55)	For welding of 5 Cr, 0.5 Mo steels and other chromium-molybdenum steels too severe for P-9018-B3 (primary for petro & petrochem industries).
	NSS-505	E505-16 (DT2616)	AC DC (+)	0.08	0.74	0.98	8.48	-	0.90	-	480 (70)	570 (58)	For welding of 9 Cr, 1 Mo steels where welding conditions are too severe for P-9018-B3 or PA502 (primary for petro & petrochem industrial).
	NSS-630	E630-16 (D630-16)	AC DC (+)	0.043	0.42	0.38	16.68	4.68	Cu 3.57	Nb&Ta 0.36	600°C x 2 hr 977 (142)	17	A precipitation hardening stainless steel used for welding of materials of similar chemical composition. Mechanical properties influenced greatly by heat treatment.
	NSS-308H	E308H-16	AC DC (+)	0.05	0.80	1.00	20.00	10.00	-	-	600 (87)	40	For welding of low carbon steels of AISI 304 type where maximum resistance to intergranular corrosion is required.
	NSS-2209	E2209-16	AC DC (+)	0.02	0.80	0.80	22.00	9.00	3.00	N 0.14	750 (109)	22	For welding duplex stainless steels for high tensile strength & improved resistance to stress corrosion cracking & pitting.
	NSS-385	E385-16	AC DC (+)	0.03	0.50	1.50	20.00	25.00	4.50	Cu 1.50	590 (85)	40	For welding of materials to similar chemical composition used in fabrication of equipment for handling sulfuric & phosphoric acid.
ACID TITANIA TYPE	NSS-308L-17	E308L-17	AC DC (+)	0.02	0.72	0.85	19.50	9.50	0.02	Cu 0.05	590 (85)	41	For welding low carbon 18% Cr - 8% Ni Steel.
	NSS-309L-17	E309L-17	AC DC (+)	0.02	0.68	0.80	24.20	13.10	0.05	Cu 0.10	620 (90)	36	For welding low carbon 22% Cr - 12% Ni steel, carbon steel or low alloy steel to stainless steel & stainless clad steel.
	NSS-310-17	E310-17	AC DC (+)	0.10	0.72	1.85	25.8	20.5	-	-	670 (97)	45	Fabrication and repair of furnace linings, furnace grates, burners, etc. Also for welding of steels with high carbon content. For joining dissimilar metals and hard to weld steels.
	NSS-312-17	E312-17	AC DC (+)	0.09	0.85	0.93	29.40	9.30	0.07	Cu 0.10	830 (120)	25	For welding of 29% Cr - 9% Ni type cast steel. Joint welding difficult-to-weld steel. For a swear resistant build up and buffer layer for hardfacing.
	NSS-316L-17	E316L-17	AC DC (+)	0.02	0.65	0.84	19.30	12.30	2.42	Cu 0.03	600 (87)	39	For welding low carbon, molybdenum-bearing austenetic alloys. Welding of 18% Cr - 12% Ni - 2% Mo steel where the corrosion resistant qualities are required.

SUBMERGED ARC WELDING FLUXES AND WIRES FOR SUBMERGED ARC WELDING (SAW) FOR STAINLESS STEEL

Type of Coating	Brand Name		SIZE (mm)	Equivalent Specifications AWS (JIS)	Typical All Weld Deposit Analysis (%)						Typical All Weld Mechanical Properties				Applications
	Flux	Wire			C	Si	Mn	Cr	Ni	Mo	Y.P. N/mm^2 (Ksi)	T.S. N/mm^2 (Ksi)	El. (%)	I.V. ºC, J (ºF, Ft-Lbs.)	
Agglomerated (Bonded) Type	NSF-S.S.	NSAW-308	2.4 3.2 4.0 4.8	ER-308	0.05	0.44	1.71	19.10	9.85	-	-	585 (85)	46	-	For 18% Cr - 8% Ni stainless steel.
	NSF-S.S.	NSAW-308L	2.4 3.2 4.0 4.8	ER-308L	0.03	0.48	1.67	19.22	9.77	-	-	570 (83)	41	-	For low carbon of 18% Cr - 8% Ni stainless steel.
	NSF-S.S.	NSAW-309	2.4 3.2 4.0 4.8	ER-309	0.05	0.45	1.48	23.47	13.30	-	-	590 (86)	39	-	For 22% Cr - 12% Ni stainless steel and dissimilar steels welding.
	NSF-S.S.	NSAW-309L	2.4 3.2 4.0 4.8	ER-309L	0.03	0.47	1.47	23.50	13.41	-	-	570 (83)	40	-	For low carbon of 22% Cr - 12% Ni stainless steel. and dissimilar steels welding.
	NSF-S.S.	NSAW-316	2.4 3.2 4.0 4.8	ER-316	0.04	0.44	1.70	19.15	12.40	2.52	-	570 (83)	40	-	For 18% Cr - 8% Ni - 2.5% Mo stainless steel.
	NSF-S.S.	NSAW-316L	2.4 3.2 4.0 4.8	ER-316L	0.03	0.46	1.73	19.20	12.50	2.47	-	550 (80)	41	-	For low carbon of 18% Cr - 8% Ni - 2.5% Mo stainless steel.

SOLID WELDING WIRE
FOR GAS TUNGSTEN ARC WELDING (GTAW) & GAS METAL ARC WELDING (GMAW)

Type of Metal	Brand Name		Size (mm)	Equivalent Specifications AWS (JIS)	Typical Analysis of Filler Wire						Typical All Weld Mechanical Properties				Applications
	TIG	MIG			C	Si	Mn	Cr	Ni	Others	Y.P. N/mm^2 Ksi	T.S. N/mm^2 Ksi	El. (%)	I.V. °C, J (°F, Ft-Lbs)	
FOR STAINLESS STEEL	NT-307	NM-307	TIG Ø 1.6 2.0 2.4 3.2 4.0 Length 1000 • MIG Ø 0.6 0.8 0.9 1.0 1.2 1.6	ER-307	0.040	0.38	4.10	20.20	9.50	Mo 1.22	432 (63)	633 (92)	42	-	For welding of mild stainless, hardened armor steels, also for buffer layers.
	NT-308/308L	NM-308L		NT-308/308L	0.025	0.37	1.85	19.80	9.85		420 (61)	560 (81)	43	-	For welding types 201, 302, 304 and 304L stainless steel.
	NT-309/309L	NM-309L		NT-309/309L	0.03	0.36	2.04	23.51	13.48		400 (58)	570 (83)	42	-	For welding similar 309 and 309L alloys or joining 300 series stainless steel to carbon or low alloy steels.
	NT-310	NM-310		ER-310	0.10	0.47	1.82	26.50	21.08		420 (61)	580 (84)	37	-	For welding type AIS 1 310, 304 clad stainless steel.
	NT-312	NM-312		ER-312	0.12	0.50	1.48	29.85	9.05		620 (90)	770 (112)	27	-	For welding dissimilar steels, high strength and high yield steels.
FOR STAINLESS STEEL	NT-316/316L	NM-316L	TIG Ø 1.6 2.0 2.4 3.2 4.0 Length 1000 • MIG Ø 0.6 0.8 0.9 1.0 1.2 1.6	ER-316/ER-316L	0.02	0.37	1.73	19.86	12.37	Mo 2.30	415 (60)	560 (81)	43	-	For welding 18% Cr - 12% Ni - 2% Mo stainless steel. Excellent corrosion resistance to sea water and nonoxidizing acids.
	NT-317/317L			ER-317/ER-317L	0.02	0.40	1.72	19.10	13.54	Mo 3.50	410 (59)	570 (83)	39	-	For welding similar stainless steels. Offers higher resistance to pitting and crevice corrosion.
	NT-320	-		ER-320	0.02	0.27	0.46	19.73	33.48	Mo 2.12 Cb&Ta 0.41 Cu 3.20	460 (67)	610 (88)	41	-	For welding similar metals in wrought and cast forms. Good corrosion resistance to a wide range of chemical environments.
	NT-330	-		ER-330	0.21	0.36	1.77	16.21	35.03		400 (58)	560 (81)	34	-	For welding similar metals in wrought and cast forms. Excellent heat and scale resistance up to 1800ºF.
	NT-347/347L	NM-347L		ER-347 ER-347L	0.03	0.41	1.68	20.22	9.87	Cb&Ta 0.88	450 (65)	616 (89)	39	-	For welding 321 and 347. Niobium stabilized reduces chance of chromium carbide precipitation and consequent intergranular corrosion.
	NT-410	NM-410	TIG Ø 1.6 2.0 2.4 3.2 4.0 Length 1000 • MIG Ø 0.6 0.8 0.9 1.0 1.2 1.6	ER-410	0.06	0.41	0.53	12.93	0.42	Mo 0.16	850ºC x 2 hr. 310 (45)	530 (77)	35	-	For welding types 403, 405, 410 and 416. Also used as overlay on carbon steels to resist corrosion, erosion or acbrasion.
	NT-410 LNb	NM-410 LNb		ER-410 LNb (ER410 LCb)	0.03	0.43	0.52	12.92	0.45	Mo 0.18 Nb&Ta 0.42	320 (46)	550 (80)	23	as weld HRC 33-40	Same as PTS-410 but with superior mechanical properties.
	NT-410 NiMo	-		ER-410 NiMo	0.03	0.41	0.54	12.15	4.12	Mo 0.62	850ºC x 2 hr. 850 (123)	950 (138)	17	as weld HRC 37-40	For welding cast and wrought material of similar chemical composition.
	NT-420	-		ER-420	0.28	0.38	0.43	13.12	0.40	Mo 0.14	860 (125)	980 (142)	45	as weld HRC 49-53 600ºC x 2hr HRC 33-36	For surfacing of overlays having good abrasion resistance. E.g. exhaust gas systems, rollers and valve faces.
	NT-430	NM-430		ER-430	0.06	0.38	0.55	16.79	0.45	Mo 0.16	850ºC x 2 hr. 310 (45)	550 (80)	30	-	For welding similar alloys, overlays and thermal spraying. Good ductility in heat-treated condition.
	NT-630 (NT-17/4)	NM-630		ER-630	0.04	0.51	0.63	16.48	4.52	Cu 3.53 Cb&Ta 0.31	AS WELD 1060 (154)	1150 (167)	9	as weld HRC 34-38	For welding similar materials. A precipitation hardening stainless steel. Mechanical properties greatly influenced by heat.

SOLID WELDING WIRE
FOR GAS TUNGSTEN ARC WELDING (GTAW) & GAS METAL ARC WELDING (GMAW)

Type of Metal	Brand Name TIG	Brand Name MIG	Size (mm)	Equivalent Specifications AWS (JIS)	C	Si	Mn	Cr	Ni	Others	Y.P. N/mm² Ksi	T.S. N/mm² Ksi	El. (%)	I.V. °C, J (°F, Ft-Lbs)	Applications
					Typical Analysis of Filler Wire						Typical All Weld Mechanical Properties				
FOR SPECIAL STEEL	NT-502	-	TIG Ø 1.6 2.0 2.4 3.2 4.0 Length 1000 • MIG Ø 0.6 0.8 0.9 1.0 1.2 1.6	ER-502	0.09	0.36	0.48	5.75			860°C x 2 hr. 380 (55)	520 (75)	29	-	For welding high strength heat treatable steels. Used in petrochemical and aircraft application.
	NT-505	-		ER-505	0.1	0.92	1.04	9.53	0.43	Mo 1.03	860°C x 2 hr. 480 (70)	570 (83)	27	-	For welding base metal of the same composition, usually in the form of pipe, tube or castings.
	NT-2553	-		ER-2553	0.02	0.40	1.23	25.53	9.52	Mo 3.73 Cu 0.8 N 0.21	590 (86)	760 (110)	28	-	Primarily to weld duplex stainless steels which contain approximately 25% Cr.
	NT-2209	-		ER-2209	0.02	0.50	1.60	23.0	8.5	Mo 3.1 N 0.17	610 (88)	805 (117)	31	-40°, 170 (-40°, 125)	For welding duplex stainless steels. High tensile strength and improve resistance to stress corrosion cracking and pitting.
	NT-2594	-		ER-2594	0.01	0.40	0.60	25.1	9.2	Mo 3.9 N 0.27	650 (94)	850 (124)	28	-40°, 90 (-40°, 66)	For welding 2507 and zeron 100 type super duplex stainless steel.
	NT-383	-		ER-383	0.02	0.22	2.63	29.2	36.4	Mo 4.35 Nb 1.83	350 (51)	550 (80)	30	-	For welding 825, alloy 28 and alloy 20. Corrosion resistance characteristics.
	NT-385 (NT-904L)	-		ER-385	0.02	0.35	1.71	20.2	25.60	Mo 4.52 Cu 1.5	410 (59)	610 (88)	35	-196°, 130 (-321°, 96)	For welding similar metals and for fabrication of equipment handling sulfuric acid and chloride containing media.

FLUX CORE WIRES
FOR FLUX CORED ARC WELDING (FCAW)

Type of Steel/ Applications	Brand Name	SIZE (mm)	Equivalent Specifications AWS (JIS)	Shielding Gas	Type of Current	Typical All Weld Deposit Analysis (%)						Typical All Weld Mechanical Properties				Applications
						C	Si	Mn	Cr	Ni	Y.S. N/mm$_2$ (kg/m$_2$)	T.S. N/mm$_2$ (kg/mm$_2$)	El. (%)	I.V. J (kgf-m)	Hardness (HV)	
STAINLESS STEEL (gas shielded)	NFCW-308LT-1	1.2-1.6	E308 LTI-1/-4 (YF308LC)	CO_2/ Ar+CO_2	DC(+)	0.03	0.62	1.56	19.5	10.5	-	400 (58)	41	-	-	Used on AISI types 301, 302, 304, 304L and 308L.
	NFCW-309LT-1	1.2-1.6	E309 LTI-1/-4 (YF309LC)	CO_2/ Ar+CO_2	DC(+)	0.03	0.60	1.40	23.6	13.1	-	386 (56)	37	-	-	Welding of similar alloys in wrought or cast forms.
	NFCW-316LT-1	1.2-1.6	E316 LTI-1/-4 (YF316LC)	CO_2/ Ar+CO_2	DC(+)	0.03	0.65	1.20	18.3	12.2	Mo 2.8	386 (56)	40	-	-	For welding AISI types 316, 316L and similar alloys.
	NFCW-410T	1.2-1.6	E410 TO-1/-4 (YF410C)	CO_2/ Ar+CO_2	DC(+)	0.06	0.20	0.47	13.0	-	-	750ºC x 2hr 372 (54)	27	-	-	Welding of base metals and similar composition.
	NFCW-410NiMoT	1.2-1.6	E410 NiMo TO-4	Ar+CO_2	DC(+)	0.04	0.23	0.36	12.2	4.1	Mo 0.70	600ºC x 1hr 614 (89)	25	-	-	Welding of AISI types 403, 405 and 410 surfacing of carbon steel to resist corrosion erosion and abrasion.

Use NIHONWELD PICKLING PASTE

* Restores stainless steel surfaces.
* Leaves a protective surface that resists corrosion.

The serviceability of a product or structure utilizing this type of information is and must be the sole responsibility of the builder/user. Many variables beyond the control of INDUSTRIAL WELDING CORPORATION affect the results obtained in applying this type of information. These variables Include, but are not limited to, welding procedure, plate chemistry and temperature, weldment design, fabrication methods and service requirements.

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