New Folder Name WELDING

"WELDING OF STAINLESS STEELS AND OTHER JOINING METHODS"
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for welding. These stainless steels also have a lower coefficient of thermal conductivity, which causes a tendency for heat to concentrate in a small zone adjacent to the weld. The austenitic stainless steels also have coefficients of thermal expansion approximately 50% greater than mild steel, which calls for more attention to the control of warpage and distortion.

An important part of successful welding of the austenitic grades, therefore, requires proper selection of alloy (for both the base metal and filler rod), and correct welding procedures. For the stainless steels more complex in composition, heavier in sections or the end-use conditions more demanding (which narrows the choice of a base metal), a greater knowledge of stainless steel metallurgy is desirable.

Two important objectives in making weld joints in austenitic stainless steels are: (1) preservation of corrosion resistance, and (2) prevention or cracking.

PRESERVATION OF CORROSION RESISTANCE

The principal criteria for selecting a stainless steel usually is resistance to corrosion, and while most consideration is given to the corrosion resistance of the base metal, additional consideration should be given to the weld metal and to the base metal immediately adjacent to the weld zone. Welding naturally produces a temperature gradient in the metal being welded, ranging from the melting temperature of the fused weld metal to ambient temperature at some distance from the weld. Selection of filler rod material is discussed beginning on Page 13, while the following discussion will be devoted to preserving corrosion resistance in the base metal heat affected zone.

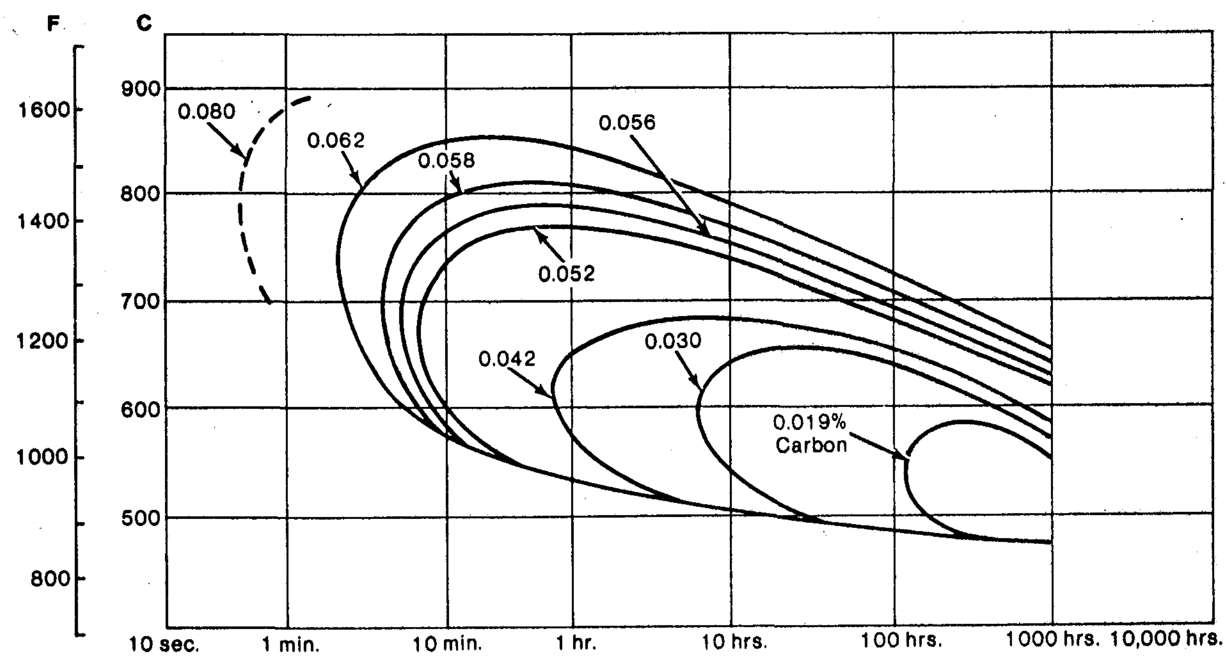
Carbide Precipitation – A characteristic of an annealed austenitic stainless steel, such as Type 304, is its susceptibility to an important microstructural change if it is exposed to temperatures within an approximate range of 800-1650F. Within this range, chromium and carbon form chromium carbides, and these precipitate out of the solid solution at the boundaries between the grains. The rapidity of carbide development depends on a number of factors, which can be illustrated by the chart in Figure 2. The actual metal temperature between the range of 800-1650F is one factor. Chromium carbides form most rapidly at about 1200F and the formation falls off to nil at the upper and lower limits. Another factor is the amount of carbon originally present in the material – the higher the carbon content the more pronounced the action. Time at temperature is a third factor.

The effect of carbide precipitation on corrosion resistance is to reduce the chromium available to provide corrosion resistance. However, the behavior of a weld-sensitized stainless steel weldment when exposed to a corrosive environment is difficult to predict. Intergranular corrosion does not always occur and there are many environments in which sensitized austenitic stainless steel are providing satisfactory service.

Because low-carbon content reduces the extent to which carbide precipitation occurs, the low-carbon austenitic grades may be preferred for weldments to be used in highly corrosive service. Type 304 with a maximum carbon content of 0.08% is widely used. Also available are low-carbon Types 304L, 316L, and 317L with 0.03% carbon.

Types 321 and 347 contain titanium and columbium-

Figure 2
Effect of Carbon Content on Carbide Precipitation



Time-Temperature-Sensitization Curves

Time required for formation of carbide precipitation in stainless steels with various carbon contents. Carbide precipitation forms in the areas to the right of the various carbon-content curves. Within time-periods applicable to welding, chromium-nickel stainless steels with 0.05% carbon would be quite free from grain boundary precipitation.

tantalum, respectively, alloying elements which have a greater affinity for carbon than does chromium, thus reducing the ssibility of chromium carbide precipitation. These stabilized types are intended for long-time service at elevated temperatures in a corrosive environment or when the low-carbon grades are not adequate.

The removal of precipitated carbides from Type 304 in order to restore maximum corrosion resistance can be accomplished by annealing (at 1800 to 2150F) (above the sensitizing range) followed by rapid cooling. Stress relieving a weldment at 1500-1700F will not restore corrosion resistance, and, in fact, may foster carbide precipitation in stainless steels that do not have a low-carbon content or are not stabilized.

The relative susceptibility of several austenitic stainless steels to sensitization during welding is shown in Table 3.

Stress-Corrosion Cracking — The chance of stress-corrosion cracking is another reason for post-weld heat treatment. In the as-welded condition, areas close to the weld contain residual stresses approaching the yield point of the material. It is difficult to predict when an environment will produce stress-corrosion cracking and to decide how much reduction must be made in the magnitude of residual stress to avoid its occurrence. To ensure against this stress-corrosion cracking in welded austenitic stainless steels is to anneal the types which contain regular carbon content, and to stress relieve the stabilized and extra-low-carbon types.

PREVENTION OF CRACKING

Two general forms of cracking have been observed to occur in welded austenitic stainless steels. They are:

1) In the weld metal during or immediately after welding.
2) In the base metal near a weld joint.

Microfissures can develop in the as-deposited weld metal shortly after solidification, or they can occur in the heat-affected zones of previously deposited (sound) beads of weld metal. Hot cracks or microfissuring gave much difficulty some years ago, but today enough is known about these cracking problems to avoid their occurrence in weldments.

The microstructure of the weld metal strongly affects susceptibility to microfissuring. Weld metal having a wholly austenitic microstructure is considerably more sensitive to conditions that promote microfissuring than weld metal containing some delta or free ferrite in an austenitic matrix. Consequently, whenever possible a ferrite-containing austenitic weld structure is employed. Selection of filler metal and the planning of a welding procedure must be done carefully to secure the small, but important amount of delta ferrite.

Much use has been made of the Schaeffler Diagram (Figure 3) for determining whether a specified weld metal composition will contain delta ferrite, and the approximate percentage. The Schaeffler Diagram, published in the mid-1940's, shows calculated ferrite content as a percentage. In 1956 the DeLong Diagram (revised 1973) (Figure 4) was published that shows ferrite content as a "Ferrite Number" (FN) rather than percent ferrite, and most welding rod suppliers now certify austenitic stainless steels by FN. The DeLong Diagram places greater emphasis on the role of nitrogen, thereby allowing more accurate calculations.

A little ferrite in a weld deposit of predominantly austenitic stainless steel, such as Type 308, for example, tends to eliminate hot cracking, a phenomenon that can destroy an otherwise well designed product. The chemical processing industry, on the other hand, sees ferrite in a different light. A

Table 3
Relative Susceptibility of the Various Grades to Sensitization During Welding

	Grade	Commercial Analysis Range			Susceptibility to Intergranular Carbide Formation Compared To Type 304 (SEE NOTE 3)			Cause of Difference			
								Carbon Content Being		Ratio of Cr & Ni to C Being	
		% Chromium	% Nickel	% Carbon	Greater	Less	None	Higher	Lower	Higher	Lower
Normal Compositions	304	18.0/20.0	8.0/10.5	0.08 max							
	302	17.0/19.0	8.0/10.0	0.15 max	X			X			X
	301	16.0/18.0	6.0/ 8.0	0.15 max	X			X			X
	305	17.0/19.0	10.5/13.0	0.12 max		Note 1			Usually X	X	
	308	19.0/21.0	10.0/12.0	0.08 max		X		Same		X	
	316	16.0/18.0	10.0/14.0	0.08 max			Approximately the same as Type 304				
	317	18.0/20.0	11.0/15.0	0.08 max			Approximately the same as Type 304				
	309	22.0/24.0	12.0/15.0	0.20 max				X		Note 1	
	309 S	22.0/24.0	12.0/15.0	0.08 max		X		Same		X	
	310	24.0/26.0	19.0/22.0	0.25 max	X			X		Note 1	
	314	23.0/26.0	19.0/22.0	0.25 max	X			X		Note 1	
Extra Low Carbon Compositions	304 L	18.0/20.0	8.0/12.0	0.03 max			Note 4		X	X	
	316 L	16.0/18.0	10.0/14.0	0.03 max			Note 4		X	X	
Stabilized Compositions	347	17.0/19.0	9.0/13.0	0.08 max			Note 2				
	321	17.0/19.0	9.0/12.0	0.08 max			Note 2				
	309 C	22.0/24.0	12.0/15.0	0.08 max			Note 2				
	318	17.0/19.0	13.0/15.0	0.08 max			Note 2				

Note 1. Depends upon exact analysis within its broad range. Carbon of Types 309, 310, and 314 is usually above 0.08% maximum.
Note 2. Formation of intergranular carbides prevented by content of stabilizing agents.
Note 3. Temperature and time at temperature constant.
Note 4. Carbide formation greatly minimized for welding but not for long-term service at elevated temperature.