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General Welding Recommendations

AL-6XN alloy is easily welded using similar weld parameters as Type 316L stainless steel, including travel speed (IPM) and weld current. It is typically suggested to use weld inserts for additional alloying when orbital or manual welding in the field.

1. Use weld insert rings.

Use weld insert rings for additional alloying when orbital or manual welding in the field. Never use filler wire in place of weld rings for sanitary tubing. Welding techniques that apply filler wire to the weld face are not recommended due to the possibility of insufficient alloying in the weld root. The insert ring alloy must have a higher molybdenum content than the AL-6XN alloy to compensate for alloy dilution on cooling. Typically Alloy C-22® (13% Mo) is used. If Alloy C-22 is not available, Alloy 625 (9% Mo) or Alloy C-276 (15% Mo) may be substituted. CSI stocks C-22 weld insert rings.

2. Place the weld ring between the two sections to be welded, and fusion weld as usual.

The weld current must be increased slightly to compensate for the increased thickness of material contributed by the insert ring.

1.

2.

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General Welding Recommendations
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3. Use inert gas for both the weld cover and backing.

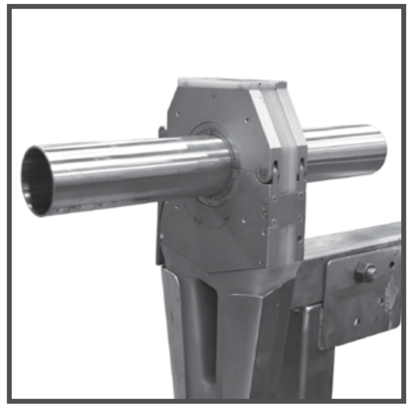
Either helium or argon may be used, although argon is more commonly used. To compensate for nitrogen that may be lost from the alloy during welding, 3-5% nitrogen may be added to both the torch and backing gas.

4. Remove heat tints.

The heat tint on tubing and welds should be no darker than a light, straw color. A color-free silver weld and heat-affected zone are best. Any darker weld heat tints must be removed before placing in service. Dark blue and black heat tints are the most susceptible to corrosion. Remove these tints using abrasives followed by acid cleaning/passivation. A poorly cleaned surface may be just as susceptible to attack as the original heat tint.

Note: Do not preheat the weld unless the material is below 50°F (10°C). When the temperature of the metal is below the dew point, allow it to warm above the condensation temperature to prevent moisture condensate on the surface. Remember: moisture can cause heat tint.

3.



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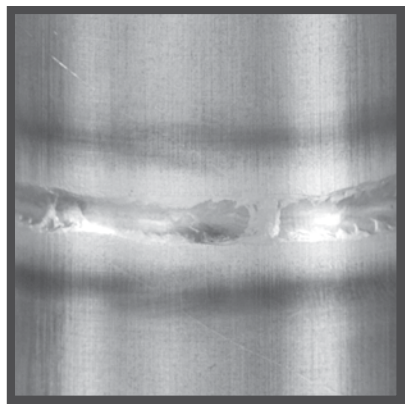

Watch the how-to video:
http://www.al6xn.com/video/Welding_AL6XN_web.mov

Special Welding Requirements

If post-weld annealing is not possible, then an additional alloy must be added to the weld. We call this an over-alloyed weld. Although AL-6XN alloy is classified as a single-phase alloy, when it is melted—as in welding—it will solidify as a three-phase alloy: austenite, chi phase, and delta ferrite.

Chi phase, a chromium-iron-molybdenum compound, depletes the grain boundary in molybdenum and chromium, which reduces corrosion resistance. Delta ferrite also exhibits poor corrosion resistance. When over-alloyed by using weld insert rings or filler, the alloy balance and, therefore, the corrosion resistance of the weld is equal to or better than the base alloy.

Autogenous Welding (without filler)

When autogenous welding, chemical microsegregation in welds causes regions to be more susceptible to localized corrosion. Autogenous welding may be used with the following precautions:

- Post-weld annealing is required. Anneal above 2150°F (1180°C) followed by rapid cooling and pickling if a protective annealing atmosphere is not used.
- The duration of anneal, at least five minutes at temperature, must be sufficient to re-homogenize the weld segregation and to dissolve any chi phase.
- Use mixed gases with a nitrogen volume of 3-5% for weld shielding.
- The G48-B crevice test may be used to assess the quality of autogenously welded and annealed AL-6XN alloy.

In many applications, a post-weld anneal and pickle may not be possible, like in large vessel fabrication or field welding of piping systems. In these cases, the exposure conditions must be carefully reviewed to determine if autogenous welds are satisfactory. Autogenous AL-6XN alloy welds are more resistant to corrosion than similar welds in Types 316L, 317L, and 904L. Such autogenous AL-6XN alloy welds have a corrosion resistance that is approximately the same as that of Alloy 904L base metal, and superior to that of Types 316L and 317L base metal.

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Weld Appearance

Weld appearance can be somewhat misleading when visually compared to hygienic welds made in 316L stainless steel. A typical AL-6XN weld will have non-uniform freeze lines and slag islands in the weld bead. These slag islands are dull or blue-gray in color and adhere to the surface. The appearance of "light" and "dark" spots on both the inside and the outside of the weld is common. The heat-affected zone can also have discoloration and is generally a little darker than conventional 316L stainless steel welds.

Acceptable weld made in **AL-6XN** electropolished tubing

Weld Test and Analysis

Welds were tested in order to identify the composition of slag islands, discoloration, and the impact of such on the integrity of AL-6XN welds. The evaluation process employed the following analytical techniques:

Scanning Electron Microscopy (SEM) determines what the surface "looks like" and determines areas for evaluation with microprobe analysis.

Energy Dispersive Spectroscopy (EDS), sometimes called microprobe analysis, determines the approximate composition of any areas in question.

X-ray Photoelectron Spectroscopy determines the molecular composition of areas or compounds present and provides light element detection.

Accelerated Corrosion Testing in a modified ASTM G48 solution identifies areas of potential corrosion attack.

Summary

1. The weld discoloration does not appear to have an effect on the corrosion resistance of the weld, and removal of the discoloration does not seem to be a requirement for good field performance.

2. Most of the discoloration observed originates from inclusions in the steel that are melted during welding and concentrated as slag on the weld. They originate in the steel-making process or enter as tramp elements from the scrap used to make up the alloy.

3. It appears that little, if anything, can be done during the welding operation to eliminate the discoloration since it comes from the steel itself.

4. The white and silver areas on both surfaces of the weld are areas free of oxides or nitrides. They represent clean surfaces.

5. The dark areas are composed of a mixture of oxides, silicates, and nitrides. They seem to come from the inclusions in the steel and possibly from the partial decomposition of the oxides in the slag. They appear to be stable and do not appear to be attacked by the very aggressive corrosion test.

Acceptable weld made in **AL-6XN** mechanically polished tubing

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References

1. AL-6XN® alloy PHYSICAL, MECHANICAL and CORROSION PROPERTIES, Bulletin No. 210, Rolled Alloys
2. Hastelloy® alloy C-276, Bulletin H-2002B, Haynes International, Kokomo, Indiana
3. INCONEL alloy 625, Bulletin T-42, Huntington Alloys Inc., Huntington, West Virginia
4. Private correspondence, Carpenter Technology Corporation, 1991

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