• Challenging Welds in Desalination Project

• Pipe Welding in Harsh Conditions

• A Popular Brew Depends on Welding

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• A Better Look at Underwater Welding
California is entering its fourth year of unprecedented drought. And with an ocean of water off its coast, finding a way to turn a drought-proof source into a potable one is seen as the best insurance policy for rapidly diminishing rivers and reservoirs. San Diego County, in particular, is especially vulnerable in this drought; the region imports over 90% of the water it uses. With sources like the Colorado River being stretched thin, compounded by the drought in the west and lack of snowpack, an innovative solution is being brought to the forefront. To ease the crisis, California looks to other countries like Israel, Saudi Arabia, and Australia, which have embraced the technology of desalination and constructed numerous plants over the past few decades.

The Carlsbad Desalination Plant, located about 35 miles north of San Diego, is a reverse osmosis (RO) seawater plant that will turn roughly 100 million gal/day of seawater into 50 million gal/year.

Welding Austenitic SMO 254 Stainless Steel for the Desalination Industry

How welders at the Carlsbad Desalination Plant are successfully welding corrosion-resistant alloys

BY MATTHEW STERNISHA
This represents about 7% of San Diego County’s usage, and diversifies the region’s water supply to a drought-proof and locally controlled supply.

Reverse osmosis desalination has been widely used in other countries to solve water shortages. This design, however, requires a pipe material that can withstand the roughly 1000 lb/in.\(^2\) required to remove the salt with osmotic pressure through the semipermeable membrane but still allows water molecules to pass through. In addition, this pipe must be able to resist the corrosive properties of seawater and a highly concentrated brine at 7% salinity, all while maintaining a minimum design life of 30 years. In the past, super duplex was the piping material of choice; however, super duplex has its drawbacks, being much more unforgiving in weldability. It also poses a potential risk of lessening its mechanical properties, toughness, and corrosion resistance if the balance of austenite and ferrite in the welded joint is not maintained.

The new choice of material is SMO 254 (UNS 31254), chosen for its ability to provide excellent resistance to corrosion (PREN>40) and pitting, for its high impact toughness, resistance to chloride stress corrosion cracking, and excellent workability and weldability.

### Joint Design and Welding Procedure

The process engineer dictated the welding parameters of the SMO 254 piping, with much of the procedure incorporating past lessons learned from years of desalination plants in operation as well as new research. The gas tungsten arc welding (GTAW) process was chosen for this welding. Although this required the most skill, it also provided the most control of heat input and of the welding variables. Typical joint design was a single V-groove butt joint, with parameters shown in Fig. 1.

Pipe thicknesses ranged from Schedule 40S (0.300 in.) to 22 mm (0.866 in.). Figures 2, 3 show a typical fitup of the piping joint with bridge tacks used to hold the fitup at the root opening.

Welding of fully austenitic stainless steels carries the potential risk of hot-cracking in the weld metal, in particular if the weldment is under constraint. In addition, an SMO 254 weldment has low thermal conductivity and high thermal expansion. Thus, heat input into the weld and welding sequence must mitigate potential distortion during the welding process. The welding procedure specification (WPS) limited the heat input to 1.5 kJ/mm at the root pass, and 0.9 kJ/mm on the cold and fill passes. This required constant monitoring of temperature and speed of the welder, certainly a tedious task for a quality control program, but necessary considering the sensitivity of the material to heat input and the risk of weld failures. The amperage range was 80–125 A on the root, with 70–100 A on the cold and fill passes.

Another element that affects heat input is the welding technique. The pipe manufacturer as well as the process engineer specified the use of a stringer bead on the welds. The stringer bead is not common to many pipefitter welders and required practice and training to ensure the correct technique was being applied within the required parameters specified by the WPS. Figure 10 shows a completed weld, which demonstrates the stringer technique used.

SMO 254 does not usually require any preheat, provided ambient temperature is above 50°F. However, maximum interpass temperature was limited to 95°C (203°F) in the WPS, again to address the material’s sensitivity to heat input and cracking.

Gas purging is critical when welding all types of stainless steel alloys to facilitate good weld pool fusion characteristics and protect the weld and heat-affected zone (HAZ) surfaces from atmospheric contamination and oxidation. Backing gas utilized was a 98% argon/2% nitrogen blend to a
purity of 0.001%. Inflatable purge gas bladders were used in the pipes to provide purge dams for the backing gas, to confine the pipeline inside purge volume to a more localized and controllable level versus purging whole pipeline sections, reducing the amount of backing gas used on the project and reducing overall cost. Shielding gas was also of the same composition, and flow rate was 20–35 ft³/min (9.34–16.4 L/min). Flow rate was controlled by the welder, and a calibrated oxygen sensor was utilized to analyze the oxygen content (<0.05% per WPS) within the argon purge gas environment. Backing gas flow rate was ranged 5–60 ft³/min (2.3–28.3 L/min). Purge gas was left in place on the weld until a weld thickness of 8 mm was achieved, at which time only shielding gas was required to finish the weld.

EW-Th-2 thoriated tungsten with DC Straight Polarity (DCSP or DCEN) was used during the GTAW process with Avesta P12 Polaris (1.6–3.2 mm diameter) ER NiCrMo-3 as the filler metal. Figure 4 shows a welder performing the root pass on the SMO 254 pipe.

Training and Union Craft Support

San Diego is certainly home to many skilled workers, on account of the Navy shipyards, numerous power plants, and other heavy industry. But welding on Alloy SMO 254 was new to the local union craft force. This presented a potential challenge to the contractor as the welder qualification is a key part of a successful project. But several steps were taken to overcome this hurdle. Job managers and supervisors met with the local union to discuss the job requirements, with local union agreeing to utilize their local training center for training and testing on the SMO 254 coupons. The contractor sent a quality control manager to the facility to assist, ensure the highest standards were held, and provide instruction during the training process. Testing was performed on 3-in.-diameter, Schedule 160 (thickness 0.436 in. or 11 mm) SMO pipe coupons in the 6G position to meet the thickness requirements for the pipe being welded at the jobsite.

Figure 5 shows a weld coupon performed by a welder during training.

All weld coupons were radiographically inspected. In addition,
the weld coupon was sent out for ASTM G41 corrosion testing, which also was required to yield acceptable results prior to the welder being job certified to weld on the plant’s pipe. It took, on average, two weeks for a welder to master the skill prior to taking and passing the welder qualification test. What resulted, however, was a new skillset for welders in San Diego County and a growing working relationship between the contractor and the Local.

Verification and Inspection

The SMO 254 pipes are critical to the process of the desalination plant. No water can be desalted with these pipes out of service. Therefore, these pipes are considered process critical, and as such, the engineer was very concerned about their reliability. In addition, the roughly 1000 lb/in.² pressure of the pipes compelled the engineer to designate the pipes as Category M fluid service pipes per ASME B31.3, which required 100% radiographic inspection on every field weld. In addition, as recommended by the process engineer, dye-penetrant testing of the root pass was performed prior to the cold and fill passes being placed, and all welds were visually inspected to the applicable ASME code.

Figures 6, 7 show dye-penetrant testing of the root pass on typical pipes at the project. The following parameters were required to be recorded during welding:

- Voltage (V)
- Amperage (A)
- Welding length/travel distance (in.)
- Welding time (s)
- Shielding gas flow rate (ft³/min)
- Backing gas flow rate (ft³/min)
- Oxygen content (%)
- Temperature (°F).

The following parameters were then calculated using the measured data:

- Travel speed (in./min) calculated by welding length (in.) + welding time (min)
- Heat input (KJ/in.)

• Heat input (KJ/in.) calculated by...
Values were then reviewed to ensure no welding passes were made that violated the parameters set forth in the WPS, particularly heat input. This required close monitoring by a quality control (QC) representative to collect the data, accurately perform the calculations, review the results, and ensure compliance. In addition, these data were retained as a record document.

Figure 9 shows a welder performing a weld with the QC monitor nearby recording the required data. Data collection for the welds and welding process on the SMO 254 alloy was an extensive undertaking by the quality control and quality assurance departments, but it was absolutely critical to mitigate potential shutdowns in the plant for repairs, as well as ensuring a long design life.

Due to the SMO 254 alloy’s sensitivity to heat input, common defects found were cracks, incomplete fusion (particularly at the sidewall), and lack of penetration. Radiographic inspection lends itself well to detect these types of defects and was the nondestructive examination of choice. All welds on the SMO 254 piping were 100% radiographic inspected.

Conclusion

Desalination has the potential for huge growth within the United States, and the Carlsbad Desalination Plant is at the forefront of that progression.

Understanding the weldability and essential variables in Alloy SMO 254 is critical if one hopes to withstand the highly corrosive properties of seawater and the osmotic pressures that must be overcome during the RO process. SMO 254 has the ability to resist corrosion in the seawater process, as well as handle the high pressures. It has superior weldability characteristics compared to other alloy options, such as duplex, but it is imperative that the risk of heat-induced cracking is considered, and measures are taken to mitigate this risk through careful monitoring and planning of the welds and weld sequence. In addition, providing training and obtaining a skilled workforce is also imperative to ensure success when working with fully austenitic stainless steels like Alloy SMO 254.

Last, a carefully controlled and documented QC program is crucial to producing sound welds, ensuring long service life, and avoiding weld failures and costly repairs in the future. Successfully welding corrosion-resistant alloys like SMO 254, utilizing the measures mentioned previously, leaves desalination poised to quench the drought and spawn a new industry within the United States.

Works Consulted

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