How To Weld Type 254 SMO® Stainless Steel

OUTO KUMPU

Material Description

Outokumpu Stainless 254 SMO® austenitic stainless steel was developed to extend the range of the common austenitic grades, particularly in handling corrosive acidic and neutral chloride-containing solutions. 254 SMO stainless steel shows excellent resistance to pitting, crevice corrosion, and stress corrosion cracking.

Forming and Machining

254 SMO is a strong, tough austenitic stainless steel. It is about 50% stronger than Type 316L and it will work harden rapidly, as do other austenitic stainless steels. 254 SMO has very good formability using standard equipment suited to the common austenitic grades. 254 SMO can be readily sheared and shaped by bending, drawing, pressing, and other common procedures. Some allowance should be made for its higher strength and the resulting greater springback. Heat treatment after cold working operations is usually not required.

If it is necessary to perform hot working operations, these procedures should be carried out within the range of 1800 to 2100°F. Higher temperatures reduce workability. Heavy scaling can occur with extended heating above 2100°F. The part should be annealed at 2100°F minimum after hot working and cooled rapidly, ideally by water quenching. This anneal is necessary to eliminate intermetallic phases possibly precipitated during hot working, and thus provide maximum corrosion resistance.

As with the common austenitic stainless steels, the toughness of 254 SMO makes it resistant to machining. However, the care taken in production of 254 SMO to achieve uniformity of composition and structure is useful in providing consistency of machining and an absence of hard spots. The machine and workpiece set-up should be rigid. Tools, whether high-speed steel or cemented carbide, should be sharp, and should be reground or replaced at predetermined intervals.

Specifications

UNS S31254 (wrought products)

UNS J93254 (cast products)

ACI CK-3MCuN (cast products)

254 SMO stainless steel is covered in the ASME Boiler and Pressure Vessel Code:
(1) Section II, Part A Ferrous;
(2) Section VIII, Division 1
(3) Section III, Division 1 under Code Cases N-439, N-440, N-441-1
(4) Section IX as P No. 8, Group 4.
254 SMO is covered under the following materials specifications:

	ASTM	ASME
Plate, Sheet, Strip	A 240, A 480	SA-240, SA-480
Bar, Billet	A 276, A 479	SA-479
Pipe, Tubing	A 249, A 269, A 270, A 312, A 358, A 409, A 813, A 814	SA-249, SA-312, SA-358, SA-409
Forging, Fittings	A 182, A 403, A 473	SA-182, SA-403
Bolts, Nuts	A 193, A 194	SA-193, SA-194
Castings	A 351, A 743, A 744	SA-351

ASME/ANSI: B16.34, B16.5, B31.1

NACE MR0175

Feed rates should be as high as possible, consistent with machine power, to minimize the effect of surface hardening. Superior lubrication and cooling are recommended. All traces of cutting fluid must be removed prior to welding, annealing, or use in corrosive service.

Equipment Assembly Codes

For maximum safety, reliability, and performance, equipment to use 254 SMO should be designed, fabricated, tested, and certified according to the latest editions and appendices of the following applicable codes:

1. Latest Edition with Addenda, ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, including Paragraph UG-99;
2. Latest Edition with Addenda, TEMA-Code for Heat Exchangers; and
3. Latest Edition with Addenda, American National Standards Institute (ANSI) B16 and B31.

The equipment should be fabricated, tested, and stamped in accordance with the applicable code. The end user should be supplied with mill test reports for all items in the fabricated equipment. These items include but are not limited to:

1. All 254 SMO products used;
2. All weld filler wires and coated electrodes;
3. All bolting materials used in fabrication and assembly that may be exposed to the process environment; and
4. All "poison pad" material used in fabrication.

Welding Fabrication — Joint Design

Joint Designs 1 through 10 suggest joint designs that are particularly effective with 254 SMO. These designs are intended to facilitate full penetration of the filler metal with minimal dilution from the base metal. They are also intended to facilitate shielding gas coverage and minimize heat input. These goals should be kept in mind when using these designs or when modifying these designs for a particular fabrication.

Gas shielded arc welding is the preferred method for the root pass with all joint designs. Gas tungsten arc welding (GTAW or TIG) with 100% argon backing purge gas and torch shielding gas should be used for all root pass welding of 254 SMO where the back or reverse side of the weldment is inaccessible, with the exception of external half-pipe coils which may be gas metal arc welded. Gas metal arc welding (GMAW or MIG) may be used to make the root pass of weldments when the back or reverse side of the weldment is accessible. Shielded metal arc welding (SMAW) with 3⁄32-inch diameter electrodes should be considered for the root pass only when the back or reverse side of the weld is accessible.

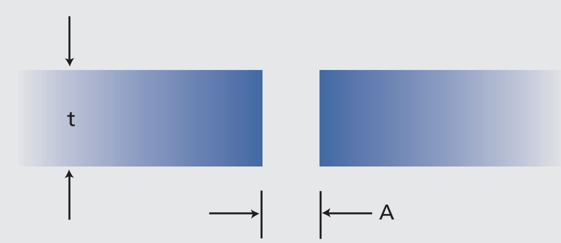
It is recommended that the ASME Boiler Pressure Vessel Code rules for operations such as welding of heads to shell, butt welding of plates of unequal thickness, attachment of pressure parts to plate to form a corner joint, and welding of nozzles and other connections into shells and heads be followed in all fabrications regardless of whether the equipment is to be code stamped or not.

The square butt weld, Joint Design 1, may be used for joining thin sheet (1⁄8-inch thickness). GTAW or GMAW may be used, with argon backing gas at a flow rate of 35–45 ft^3/hr and with electrode shielding gas at 25 ft^3/hr for GTAW and at 35–45 ft^3/hr for GMAW. SMAW should use 3⁄32-inch diameter electrodes.

For Joint Designs 2 through 9, once the root pass has been accomplished by GTAW or SMAW, the remainder of the joint may be filled by GTAW, GMAW, or SMAW. Thicknesses of 254 SMO from 1⁄8 inch to 1⁄2 inch should be beveled to form a "V" groove (Joint Design 2). They should be

Square Butt Joint

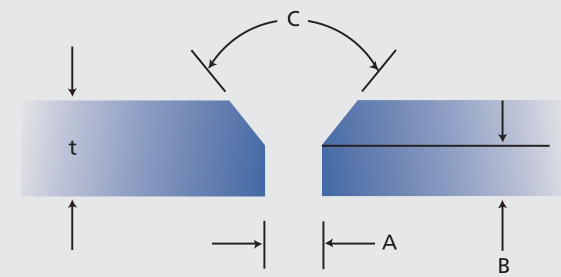
Joint Design 1



Maximum t = 0.125 inch
Gap A = 0.040 – 0.080 inch

Single "V" Joint

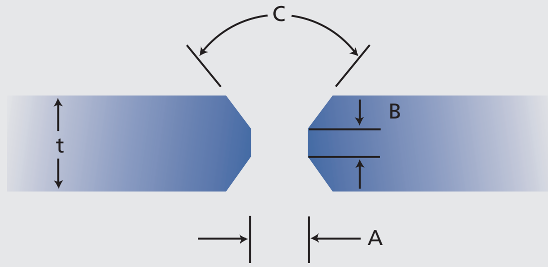
Joint Design 2



t = 1⁄8 to 1⁄2 inch
Welding with SMAW
A = 0.10 – 0.12 inch
B = 0.06 – 0.08 inch
Angle C = 60°

Welding with GTAW Gap
Gap A = 0.06 – 0.12 inch Land
Land B = 0.04 – 0.06 inch
Angle C = 85°

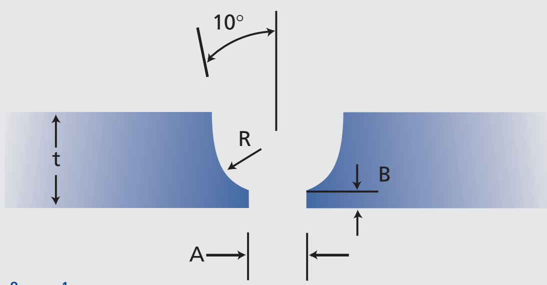
Double "V" Joint
Joint Design 3



t = ½ inch or greater

Welding with SMAW	Welding with GTAW
Gap A = 0.10 – 0.12 inch	Gap A = 0.06 – 0.12 inch
Land B = 0.06 – 0.08 inch	Land B = 0.04 – 0.06 inch
Angle C = 60°	Angle C = 85°

Single "U" Joint
Joint Design 4



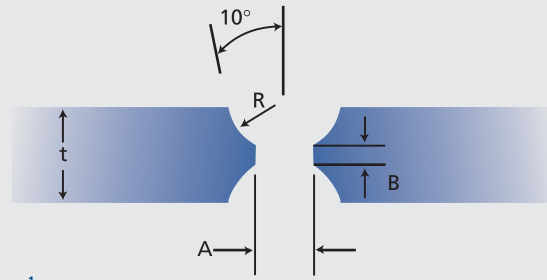
t = ¾ – 1¼ inch
Gap A = 0.10 – 0.12 inch
Land B = 0.06 – 0.08 inch
Radius R = ⅜ inch minimum

For single groove welds on heavy plate thicker than ¾ inch. Reduces the amount of time and filler metal required to complete the weld.

welded using a purged backing bar (see Fixtures) unless welding both sides or welding by SMAW. Thicknesses of 254 SMO greater than ½ inch should be beveled to form a double "V" (Joint Design 3). Thicknesses over ¾ inch may be beveled to form a single or double "U" (Joint Designs 4 and 5). Joint Designs 6 through 10 are useful for the special situations indicated.

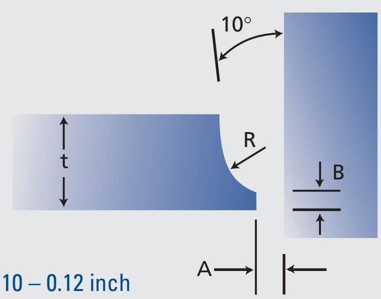
Each weld pass should be deposited as a straight stringer bead. Weaving can cause excessive heat input. Welding should be done in the flat or downhand position whenever possible. Welding sequence should be carefully selected to minimize the stresses during welding. All joint designs should be modified as necessary to ensure full penetration of the filler to the bottom of the joint. Incomplete penetration leaves undesirable crevices and voids on the underside of joint sites that may be subject to accelerated corrosion attack or to stress concentration, leading to mechanical failures.

Double "U" Joint
Joint Design 5



t > 1¼ inch
Gap A = 0.10 – 0.12 inch
Land B = 0.06 – 0.08 inch
Radius R = ⅜ inch minimum

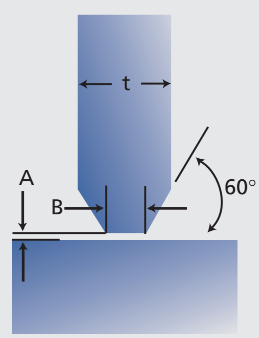
"J" Groove Joint
Joint Design 6



Gap A = 0.10 – 0.12 inch
Land B = 0.06 – 0.08 inch
Radius R = ⅜ inch minimum

For single groove welds on plates thicker than ¾ inch. Reduces the amount of time and filler metal required to complete the weld.

"T" Joint
Joint Design 7

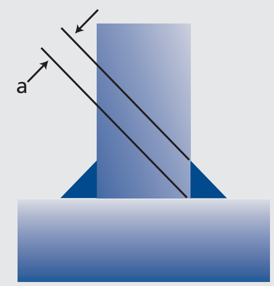


t = 5/32 to ¾ inch
A = 0 – 0.02 inch
B = 0.06 – 0.08 inch

For joints requiring maximum penetration. Full penetration welds give maximum strength and avoid potential crevice corrosion sites.

"T" Joint

Joint Design 8

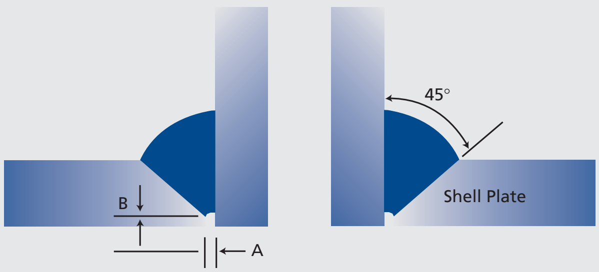


a = 0.7 x t to 1.0 x t

Conventional fillet weld. Fillet size should equal the thickness of the thinner member. This joint design is not suited to withstand mechanical fatigue loading. The built-in crevice in this joint must be completely sealed to prevent corrosion.

For Openings such as Manways, Viewports and Nozzles

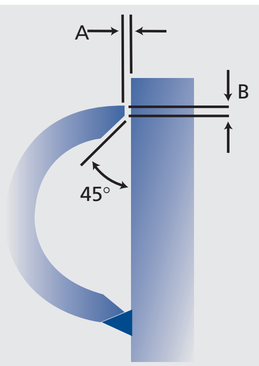
Joint Design 9



Gap A = 0.10 – 0.12 inch
Gap B = 0.06 – 0.08 inch

For Installing Half Pipe Coil to Vessel, Sidewalls and Tank Bottoms

Joint Design 10



A = 0 – 0.02 inch
B = 0.06 – 0.08 inch

Internal bevel allows for full penetration weld and eliminates the crevice which is a potential corrosion site.

Welding Fabrication — Surface and Edge Preparation

Cleanliness is a very important factor in welding 254 SMO because introduction of impurities can greatly reduce corrosion resistance. Shop dirt, oil, grease, crayon marking, cutting fluids, sulfur compounds, marking inks, etc. must be removed from the welding surface and from a band at least two inches wide on each side of the weld. Vapor degreasing or scrubbing with a suitable solvent are appropriate methods. Paint or other adherent materials may require use of alkaline cleaners or proprietary compounds. If the alkaline cleaners contain either sodium sesquisilicate or sodium carbonate, the cleaner should be removed by scrubbing with hot water.

Beveling is best accomplished by machine — usually a plate planer or other machine tool. Hand grinding, carefully performed, can be satisfactory. The land must be a true land and not a dull knife edge. The edges of the sheet or plate should be squared, aligned, and tack welded prior to welding. The gap, as shown in the recommended Joint Designs, is essential to achieve welds of maximum corrosion resistance. Excessive dilution from the base metal is to be avoided. Square butt joints cannot be used for 254 SMO over about 0.125 inch in thickness.

Welding Fabrication — Preheating and Postheating

Preheating of 254 SMO is not recommended, except to the extent that cold material may be heated to room temperature (>50°F) to prevent condensation of moisture in the weld area. If oxyacetylene preheating is used for this purpose, the heat should be applied evenly on the base metal rather than on the prepared edge to avoid carbon pickup. Hot spots must be avoided.

Postweld heat treating is unnecessary and probably harmful. The only exception relates to an autogenous weld. It is recommended that all autogenous welds be avoided. However, in the event that an autogenous weld occurs, it is necessary to give it a full anneal and quench to restore corrosion resistance. This treatment requires uniform heating to 2100°F minimum and very rapid cooling, ideally water quenching.

Welding Fabrication — Gas Tungsten Arc Welding

Equipment

Gas Tungsten Arc Welding (GTAW), commonly called TIG, may be performed manually or by machine. A constant–current power supply should be used, preferably equipped with a high frequency circuit for starting the arc and a stepless control current decay unit incorporated in the power supply unit. GTAW should be done using direct-current straight polarity (DCSP), electrode negative. Use of direct-current reserve polarity (DCRP) will produce rapid electrode deterioration.

Electrode Selection and Use

The non-consumable electrode should comply with AWS Specification A5.12, Classification EW Th-2 (2% thoriated tungsten electrode). The consumable electrode (weld filler metal) should comply with AWS Specification A5.14 and ASME Specification SA 5.14. The AWS electrode classification is ERNiCrMo-3. Alloy 625 or Outokumpu Stainless P12 is appropriate. Other filler metals with sufficient chromium and molybdenum content to ensure adequate corrosion resistance, such as Outokumpu Stainless P16, Alloy C-276, or C-22, may also be considered.

For GTAW, good arc control is obtained by grinding the tungsten electrode to a point. Vertex angles of 30 to 60 degrees with a small flat at the point are generally used. For automatic GTAW, the vertex angle has an influence on penetration characteristics. A few simple tests to determine correct electrode configuration should be made before actual fabrication.

When welding a dissimilar metal such as another austenitic stainless steel, a low alloy steel, or carbon steel to 254 SMO, Alloy 625 filler may be used. However, better and more economical results can be achieved using a stainless steel electrode such as E309LMo or other low-carbon electrode with alloy content intermediate to the dissimilar metals. When welding 254 SMO to a dissimilar metal, the welder should consider the differences in thermal expansion and conductivity to minimize the possibilities of weld cracking and distortion.

Weld Pool Protection

The weld pool in GTA welding should be protected from atmospheric oxidation by inert gas flowing through the welding torch. The turbulence of the inert gas, and the resulting entrainment of atmosphere, should be minimized by use of a gas diffuser screen (gas lens) on the torch.

Operating procedures should be adjusted to ensure adequate inert gas shielding. Gas flow should precede arc initiation by several seconds and should be held over the weld pool for at least five seconds after the arc is extinguished. If flow is too low, the weld pool will not be adequately protected. If flow is too high, gas turbulence may aspirate air into the weld region. Argon backing gas is required on the back side of the joint for all root passes, regardless of joint design. The argon should be welding-grade 100% argon, having a purity of 99.9% argon and a dew point of -77°F.

Approximate flow rates are 25 cubic feet per hour for the electrode and 35 to 45 cubic feet per hour for the backing purge. The enclosed volume should be purged a minimum of seven times before welding begins. Argon should be fed in at the bottom and out at the top because of its weight relative to air.

Additions of oxygen and carbon dioxide should be avoided for metallurgical reasons. A small addition of dry nitrogen may be considered. An addition of helium may also be useful under some circumstances.

There should be regular inspections of O-rings for watercooled torches and of gas hoses to ensure that only the pure, dry shielding gas is delivered to the part.

GTAW Deposit Techniques

The joint should be prepared in one of the geometries shown in Joint Designs 1 through 10 with attention given to surface preparation, edge preparation, alignment, root spacing, and installation of a backing bar to ensure full argon backing gas coverage while making tack welds and the root pass.

Ignition of the arc should always take place within the joint itself. Any strike scars alongside the joint should be removed by fine grinding.

Tack welds of appropriate length and spacing should be made with full argon shielding. The root pass should be made using Alloy 625 or Outokumpu Stainless P12 filler and the appropriate shielding gas flow. The arc energy input should not exceed 38 kJ/inch. There should be no tack weld at the starting point of the actual root pass weld. To avoid cracking in the root pass related to tack welds, the welder should interrupt the root pass before a tack weld. The welder should either grind away the tack completely with a slitting wheel grinder, or make the tack shorter by grinding the start and finish of the tack prior to recommencing the root pass. The width of the root gap should be maintained against shrinkage.

The start and finish of the root pass weld should be ground off prior to the start of any filler passes. Straight stringer beads should be used. The metal should be allowed to cool to less than 212°F between passes. The joint may be filled using additional passes with 1⁄16-, 3⁄32-, or 1⁄8-inch diameter filler metal with 100% argon shielding gas. GTA welding generally gives the best results when done in the flat position but vertical welds can be made successfully. The torch should be as close to perpendicular to the workpiece as possible.

Excessive deviation from perpendicular may cause air to be drawn into the shielding gas. The filler wire should be kept clean at all times. Filler wire should be stored in a covered container when not in use.

After welding, any heat tint should be removed by fine grinding, using as fine an abrasive as possible while still removing heat tint in a reasonable time. Abrasive blasting with 75 to 100 micron soda-lime glass beads is also acceptable. The use of carbon steel brushes is prohibited. Even stainless steel brushes using common grade stainless for the wire are not acceptable unless there is to be subsequent chemical cleaning of the weld. These precautions are designed to prevent iron contamination of the surface that might initiate attack in aggressive chloride environments. Alternatively, heat tint may be removed by use of Avesta Welding Products RedOne 140 paste or 240 spray gel or acid treatment followed by thorough rinsing of the acid from the metal.

Welding Fabrication — Gas Metal Arc Welding

Equipment

Gas Metal Arc Welding (GMAW), commonly called MIG, is performed using a constant voltage power supply with variable slope and variable inductance control or with pulsed arc current capability. Three arc transfer modes are available:

Short Circuiting Transfer

The power source must have separate slope and secondary inductance controls. It is used for material up to 0.125 inch thick. Short circuiting transfer occurs with low heat input and is particularly useful when joining thin sections that could be distorted by excessive heat. It is also useful for out-of-position welding.

Pulsed Arc Transfer

Two power sources are required, one for each of the two ranges. Switching sources produces the pulsed output. The current has its peak in the spray transfer range and its minimum in the globular range. This method provides the benefits of spray arc but limits heat input, making the method useful in all positions.

Spray Transfer

Spray transfer is accompanied by high heat input but it gives a stable arc and high deposition rates. It is generally limited to flat-position welding. Because of total heat input considerations, short circuiting transfer and pulsed arc transfer are preferred methods of GMAW for 254 SMO. GMAW should be done with direct-current reverse polarity (DCRP), electrode positive.

Electrode Selection and Use

GMAW uses a consumable electrode in the form of a continuous solid wire usually supplied on a layer-wound spool and fed through the GMA torch by an automatic wire feed system. This electrode (weld filler) shall comply with AWS Specification A5.14 and the ASME Specification SA5.14. The AWS electrode classification is ERNiCrMo-3.

Alloy 625 or Outokumpu Stainless P12 are acceptable fillers. As noted for GTAW, Outokumpu Stainless P16, Alloy C-276, or similar fillers may also be considered. Other fillers may be considered when joining dissimilar metals. The common wire sizes for GMAW are smaller than those for GTAW, the most common being 0.035, 0.045, and 0.062 inch.

The speed of electrode feed is a direct function of welding current and wire diameter.

Typical welding parameters for spray arc transfer, using 99.95% argon shielding gas, 35 to 55 ft^3/hr, are:

Table 1

Wire Diameter (inch)	Amperes	Volts
0.035	170-190	28
0.035	220-280	30
0.062	280-330	31

Typical welding parameters for short circuiting arc transfer, using 99.95% argon shielding gas, 25 to 45 ft^3/hr, are:

Table 2

Wire Diameter (inch)	Amperes	Volts
0.035	90-120	19-21
0.045	110-140	20-22

If helium is added to flatten the bead, the shielding gas flow rate should be at the upper end of the range.

Weld Pool Protection

The weld pool in GMA welding should be protected from atmospheric oxidation by inert gas flowing through the GMA torch. The shielding gas is typically 100% welding-grade argon, but up to 25% helium may be used for pulsed arc or short circuiting arc welding. Another gas that has satisfactory results is argon — 30 to 35% helium — 0.5 to 1.5% carbon dioxide. Appropriate flow rates are 45, 50, and 55 ft^3/hr for 0.035, 0.045, and 0.062 inch diameter wire, respectively. There should be regular inspections of O-rings in water-cooled torches and of gas hoses. Welding in the presence of air drafts, regardless of weld position, should be avoided.

Deposit Techniques

The joint should be prepared in one of the geometries shown in Joint Designs 1 through 10, with attention given to surface preparation, edge preparation, alignment, root gap, and installation of a backing bar to ensure full argon backing gas coverage while making tack welds and the root pass.

Ignition of the arc should always take place within the joint itself. Any strike scars alongside of the joint should be removed by fine grinding.

Tack welds of appropriate length and spacing should be made with full argon shielding. The root pass should be made using Alloy 625, Outokumpu Stainless P12, or Outokumpu Stainless P16 filler with the appropriate shielding gas flow. The arc energy input should not exceed 38 kJ/inch. There should be no tack weld at the starting point of the actual root pass weld. To avoid cracking in the root pass related to tack welds, the welder should interrupt the root pass before a tack weld. The welder should either grind away the tack completely with a slitting wheel grinder, or make the tack shorter by grinding the start and finish of the tack prior to recommencing the root pass. The width of the root gap should be maintained against shrinkage.

The start and finish of the root pass weld should be ground prior to the start of any filler passes. Straight stringer beads should be used. The metal should be allowed to cool to less than 212°F between passes. The joint may be filled using additional passes with 0.035- or 0.045-inch diameter Alloy 625, Outokumpu Stainless P12, or Outokumpu Stainless P16 filler metal with 100% argon backing gas and either 100% argon or 75% argon–25% helium shielding gas. GMA welding generally gives best results when done in the flat position but vertical welds can be made successfully. The torch should be as close to perpendicular to the workpiece as possible. Excessive deviation from perpendicular may cause air to be drawn into the shielding gas. The filler wire and guide tube should be kept clean at all times. Filler wire should be stored in a covered container when not in use.

After welding, any heat tint should be removed by fine grinding, using as fine an abrasive as possible while still removing heat tint in a reasonable time. Abrasive blasting with 75 to 100 micron soda-lime glass beads is also acceptable. The use of carbon steel brushes is prohibited. Even stainless steel brushes using common grade stainless for the wire are not acceptable, unless there is to be subsequent chemical cleaning of the weld. These precautions are designed to prevent iron contamination of the surface that might initiate pitting in aggressive chloride environments. Alternatively, heat tint may be removed by use of Avesta Welding Products RedOne 140 paste or 240 spray gel or acid treatment, followed by thorough rinsing of the acid from the metals.

Welding Fabrication — Shielded Metal Arc Welding

Equipment

Shielded Metal Arc Welding (SMAW), commonly called stick or covered electrode welding, is performed using a constant- current power supply. SMA welding is done using direct-current reverse polarity (DCRP), electrode positive.

Electrode Selection and Use

SMA welding uses a consumable electrode in the form of a core wire covered by a coating. The coating provides arc stability, shields the molten metal during arc transfer, and protects the weld during solidification. In some cases, the coating may provide a portion of the alloy content of the weld filler. The consumable electrode should comply with AWS Specification A5.11. The AWS electrode classification is ENiCrMo-3 for the 112 electrode. (Outokumpu Stainless P12R electrode has AWS coverage as ENiCrMo-12). As noted for GTAW, Alloy C-276, Outokumpu Stainless P16, or similar fillers may also be considered. These electrodes can be used in all positions.

Electrodes are furnished in airtight containers because moisture in the electrode coating will produce weld porosity and poor bend ductility. Once the container is opened, the electrodes should be stored in a commercial electrode oven heated to at least 200°F to maintain dry coating.

The operating current required to achieve good welding characteristics increases with increasing electrode diameter. Typical SMA welding parameters are shown in Table 3.

Table 3

Electrodes Diameter (inch)	Welding Current Amperes
3⁄32	40-70
1⁄8	60-95
5⁄32	90-135

Weld Pool Protection

For SMAW, the weld pool is protected by gases and slag from the electrode coating. To maximize this protection, the welder should hold as short an arc as possible. “Long arc” and increased gap between electrode and workpiece can produce weld porosity, excessive oxides, excessive heat input, and reduced mechanical properties. Welding in the presence of air drafts should be avoided.

Deposit Techniques

The root pass should be made with 3⁄32-inch diameter electrodes. Larger electrodes may be used for subsequent filler passes. Ignition of the arc should always occur within the joint itself. Any strike scars alongside of the joint should be removed by fine grinding.

For 254 SMO, SMA welding should not be used for base material less than 0.125 inch in thickness. For optimal speed and economy, the workpiece should be in the flat position. The electrode should be held at 20 degrees (drag angle) from the perpendicular, with the electrode grip inclined toward the direction of travel. The metal should be deposited in a straight stringer bead, with the width of weave not exceeding two times the electrode diameter. The current should be set only high enough to obtain a smooth arc and good fusion of weld to base metal. The arc energy input should not exceed 38 kJ/inch.

The start and finish of each filler pass should be ground off prior to the start of the next filler pass. The metal should be allowed to cool to less than 212°F prior to the start of the next filler pass. All slag material must be removed from each filler pass. After welding, any heat tint should be removed by fine grinding, using as fine an abrasive as possible, while still removing heat tint in a reasonable time. Abrasive blasting with 75 to 100 micron soda-lime glass beads is also acceptable.

The use of carbon steel brushes is prohibited. Even stainless steel brushes using common-grade stainless for the wire are not acceptable, unless there is to be subsequent chemical cleaning of the weld. These precautions are designed to prevent iron contamination of the surface that might initiate pitting in aggressive chloride environments. Alternatively, heat tint may be removed by use of Avesta Welding Products RedOne 140 paste or 240 spray gel or acid treatment, followed by thorough rinsing of the acid from the metal.

When SMA welding is used for the root pass, the root side should subsequently be ground smooth. All weld spatter, slag, and heat tint should be removed.

SMA welds may be subject to starting porosity because the electrode requires a few seconds to generate sufficient shielding to protect the arc. Voids at the end of a weld are usually attributed to shrinkage caused by the sudden extinction of the arc. This problem is overcome by a slight backstepping, a momentary reversal in travel just before the arc is broken. To obtain the highest quality weld deposits, the best practice is to grind all starting and stopping points.

Welding Fabrication — Submerged Arc Welding

Earlier publications indicated that submerged arc welding (SAW) should not be applied to 254 SMO steel because of risk of carbon or silicon pick-up from the flux. There was also the risk of microfissuring associated with the relatively high heat input of SAW. These concerns have been addressed. SAW, with appropriate controls, is now commonly applied to 254 SMO. For example, SAW is regularly used in production of heavy-wall pipe.

Selection of flux is important. Avesta Welding Products 805 flux was designed for highly alloyed stainless steels. This chromium-enriched flux provides good weldability, good ease of removal, and superior final appearance.

Control of heat input to prevent microfissuring is critical. Precautions include adherence to heat input limitations, use of small-diameter wire, use of U-joints where possible, and uniformity of the joint geometry and alignment. Limitation of interpass temperature is essential.

Welding Fabrication — Prohibited Welding Processes

Oxyacetylene welding cannot be used for 254 SMO because carbon pick-up from the flame will substantially lower corrosion resistance.

Autogenous welding (no filler metal), regardless of welding process, should not be used because microsegregation within the weld metal during solidification will greatly reduce corrosion resistance. Corrosion resistance of an autogenous weld can be recovered by a full anneal and quench, but such practice is seldom applicable to practical engineering constructions, whether new or repair welding. In the application of the recommended welding practices, care must be taken in the geometry and performance of the weld that there is no opportunity for autogenous solidification.

Welding Fabrication — Interpass Temperatures and Cooling

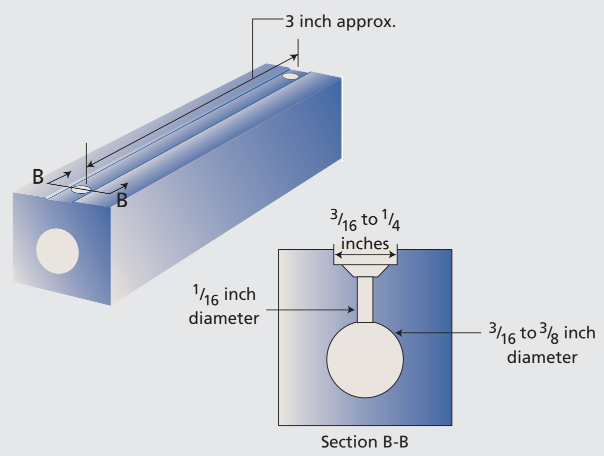
Interpass temperature of 254 SMO should not exceed 212°F. Auxiliary cooling methods may be used between passes to speed the overall welding operation, provided that they do not introduce contamination of the joint. Examples of contamination may include oil from a shop air line, grease or dirt from water-soaked rags, or even mineral deposits from hard water.

When attaching hardware to the exterior of a thin-walled vessel, the fabricator should provide auxiliary cooling to the inside of the vessel wall to minimize heat-affected zone effects. The surface temperature of the internal vessel surface of 254 SMO should not exceed about 1100°F.

Welding Fabrication — Controlling Distortion

Controlling distortion of 254 SMO is not significantly different from controlling distortion of the common austenitic grades. It may actually be easier because of the low heat input practices used for 254 SMO. Good practice includes proper fixturing, cross supports, bracing, staggered bead placement and weld sequence, etc. The edges of the plate or sheet should be squared, aligned, and tacked prior to welding.

Groove Design for Backing Bars Figure 1



Square-corner groove employed with backing gas (groove depth depends on gas flow required and length of bar).

Welding Fabrication — Fixtures

A square-corner, grooved backing bar is recommended for providing inert gas coverage during root passes. A typical chill bar cross-section is shown below, featuring a square-corner groove and drilled holes for gas purging. Groove depth is a function of the gas flow required and the length of the bar. The backing bar also serves as a chill to the base metal and a support to prevent excessive penetration of the weld bead.

It is essential that there not be abrasive contact of 254 SMO with copper or brass in any area that is to be subsequently welded. Penetration of copper or zinc into grain boundaries can give rise to crack formation.

Descaling, Pickling, and Surface Condition

Oxide, tarnish, heat tint, or other surface contamination can be removed by mechanical or chemical methods, ideally a combination of the two. Mechanical methods include fine grinding and polishing and abrasive blasting with 75 to 100 micron soda-lime glass beads. Subsequent chemical cleaning is not required after either of these methods, but subsequent chemical cleaning is good practice because it guards against contamination from the mechanical cleaning medium.

Wire brush cleaning is generally insufficient unless it is followed by chemical cleaning. Steel wire brushes, and even stainless steel wire brushes, can leave behind a residue of iron contamination that could lead to initiation of pitting in aggressive chloride environments.

Prior to any chemical cleaning, the user should consult ASTM A 380 regarding correct procedures and precautions. Chemical cleaning is readily accomplished using a pickling solution of 20% nitric acid–5% hydrofluoric acid in water, commercially available solutions or pastes of similar ingredients, or Avesta Welding Products RedOne 140 paste or 240 spray gel.

Proper precautions must be taken when handling pickling solutions and pastes. Positive ventilation is required to remove fumes. Protective clothing, face shields, and rubber gloves must be worn. Proper environmental procedures are required for the disposal of wash liquors from pickling operations.

Workmanship, Inspection, and Quality Control

The ease of fabrication of 254 SMO is intermediate to that of austenitic stainless steels, such as Type 316L or 317L, and that of nickel-base alloys, such as Alloy G or 625. Consequently, fabrication should be performed by skilled workers, ideally ASME Code–qualified in these other alloys. With such experience, workers require only brief familiarization procedures.

Because 254 SMO is frequently selected for service in components critical to process operations, the welds should be rigorously inspected. Straight stringer beads with a distinct crown (convex surface) are essential to best quality. No pits, porosity, cracks, pinholes, slag inclusions, undercutting, overheating, or other weld defects should be accepted in fabricated equipment. Complete penetration is required on the entire length of weld. Arc strikes and breaks outside of the weld zone must be removed by fine grinding. Care must be taken that all slag is removed between passes. All weld spatter should be removed by fine grinding.

In addition to mandatory non-destructive tests required for ASME Code fabrications, it is recommended that other test methods such as radiographic, dye-penetrant, ultrasonic, and hydrostatic be used where practical, to ensure best weld quality. Such tests are useful both for intermediate inspections during fabrication and for final inspection.

All rejectable weld defects should be completely removed by grinding. The ground crater should be dye-penetrant inspected to ensure that the defect is completely removed. The area of the repair should be thoroughly cleaned and then welded by one of the described procedures. It is not good practice to attempt to heal cracks or wash-out defects by remelting of weld beads or by deposition of additional weld beads.

Outokumpu Stainless Welding Consumables

Avesta Welding Products, Inc. provides coated electrodes, wires for GTAW, GMAW, and SAW, pickle paste, pickle spray, and welding fluxes, all of which have been formulated to produce excellent results when welding 254 SMO. For these products, call Avesta Welding Products, Inc. at 1-800-441-7343.

Technical Support

Outokumpu Stainless, Inc. assists users and fabricators in the selection, qualification, installation, operation, and maintenance of 254 SMO stainless steel. Technical personnel, supported by the research laboratory of Outokumpu Stainless, can draw on years of field experience with 254 SMO to help you make the technically and economically correct materials decision.

Outokumpu Stainless is prepared to discuss individual applications and to provide data and experience as a basis for selection and application of 254 SMO.

Outokumpu Stainless works closely with its distributors to ensure timely availability of 254 SMO in the forms, sizes, and quantities required by the user. For assistance with technical questions and to obtain top quality 254 SMO, call Outokumpu Stainless at 1-800-833-8703.

Outokumpu Stainless, Inc. is pleased to acknowledge the contribution to the original manuscript for this recommended welding practice by Ralph J. Valentine, VAL-CORR Corp., Portage, Michigan.

1064 EN, Schaumburg, USA. December 2004.

Outokumpu Stainless is a core business within Outokumpu, a dynamic metals and technology group operating worldwide and marketing its metals, metal products, technology and services to customers in a wide range of industries.

Outokumpu Stainless, Inc., 425 North Martingale Road, Suite 1600, Schaumburg, IL 60173-2218 USA
Tel. 1-800-833-8703 Fax 1-800-545-8617 stainless.info@outokumpu.com