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WELDING STANDARDS

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NTO-S-0035

WELDING STANDARDS

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FINAL ISSUE
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TABLE OF CONTENTS

(Continued)

<u>SECTION</u>		<u>PAGE</u>
VIII	5.6 Gas Metal Arc Welding on Aluminum	VIII-1
IX	5.6 Gas Tungsten Arc Butt Welding of Invar with a Root Gap	IX-1
X	5.6 Gas Tungsten Arc Butt Welding of Invar to Stainless Steel with a Root Gap	X-1
XI	5.6 Gas Tungsten Arc Butt Welding of Carbon Steel to Stainless Steel with a Root Gap	XI-1
XII	5.6 Manual Shielded Metal Arc Butt Welding of Carbon Steel to Stainless Steel with a Root Gap	XII-1

FIGURES

1	EDGE PREPARATION
2	EDGE PREPARATION
3	LOCATION OF 'Y' RING
4	MEAN AMPERAGE VALUES
5	MEAN AMPERAGE VALUES
6	TEST WELD FOR EQUIPMENT CHECK

1.0 PURPOSE

The purpose of this Standard is to establish the use of standard welding techniques through procedure implementation, and specification and operator qualification.

2.0 QUALIFICATION GUIDE

2.1 WELDER QUALIFICATION

2.1.1 Welders performing welding on the test article and directly associated hardware using this procedure shall be qualified in accordance with MIL-T-5021 or NTO-QCS-111.

2.1.2 Welders performing welding on all support equipment or hardware using this procedure shall be qualified in accordance with MIL-STD-248.

2.1.3 A weld procedure must be satisfactorily qualified in accordance with the required certification test and submitted for approval prior to the performance of any production welding.

2.2 QUALIFICATION OF NONDESTRUCTIVE TESTING (NDT) PERSONNEL

2.2.1 Personnel performing nondestructive testing shall be qualified in accordance with NTO-QRI-13.1.

3.0 REQUIREMENTS

3.1 NONDESTRUCTIVE TESTING (NDT)

3.1.1 All liquid penetrant examinations, if specified on the drawing or applicable NTO specification, shall be performed in accordance with NTO-QCS-107.

- 3.1.2 All magnetic particle examinations, if specified on the drawing or applicable NTO specification, shall be performed in accordance with NTO-QCS-108.
- 3.1.3 All radiography, if specified on the drawing or applicable NTO specification, shall be performed in accordance with NTO-QCS-105A.

3.2 CLEANLINESS LEVEL

- 3.2.1 Welding operations conducted as the final weld on a piping system which has previously been cleaned to a precision cleanliness level shall not contaminate the subject system. The welding operation cleanliness shall conform to NTO-QCS-112 with the level established for the system.
- 3.2.2 Where a line which has been certified clean is affected, appropriate plugging methods are to be used to maintain system cleanliness, i.e., plastic bags or expandable plugs. Prior to and after removing the plug, the entire weld area and the affected area shall be wiped clean with a lint-free cloth saturated with reagent-grade Methyl Ethyl Keton (MEK) for the removal of grease, finger prints, or other contaminants.

3.3 IDENTIFICATION

- 3.3.1 Each weld shall be identified with a symbol orienting its location and the welding operators symbol.
- 3.3.2 Symbols shall be vibratol etched adjacent to the weld on the base metal. Penetration of the etch shall be

done in a workmanshiplike manner, limited to producing a readable image and shall not cause damage to the welded assembly.

4.0 APPLICABLE DOCUMENTS

The following specifications and publications of the issues indicated by date form a part of this specification to the extent specified herein. Where no date is indicated, the applicable issue shall be the latest in effect.

Military

MIL-STD-248	Qualification Tests for Welders
MIL-T-5021	Tests: Aircraft and Missile Welding Operators Qualification
MIL-STD-410	Qualification of Inspection Personnell, Magnetic Particle and Penetrant
MIL-R-5031	Rods and Wire, Welding, Corrosion and Heat Resistant Alloys
MIL-R-5632	Rods; Steel Welding
MIL-E-22200-2	Electrodes, Welding, Covered (Austenitic Chromium Nickel Steel) for Corrossive and High Temperature Service
MIL-E-22200/1	Electrodes, Welding, Mineral Covered, Iron Powder, Low Hydrogen Medium and High Tensile Steel, AS welding or Stress - Relieved Application.
MIL-E-16053	Electrodes, Welding, Bare, Aluminum Alloys

Other

NTQ-QCS-112	Levels of Cleanliness
NTQ-QCS-107	Liquid Penetrant Examination of Weldments
NTQ-QCS-108	Magnetic Particle Examination of Weldments

NTO-QCS-105A	Radiography of Fusion Welds
NTO-QCS-111	Missile Welding Operators Qualification
NTO-QRI-131	Certification of Non-Destructive Testing Personnel
ASME, Sec. VIII	Unfired Pressure Vessel Code

5.0 WELDING PROCEDURE

5.1 INERT GAS INTERIOR PURGE

5.1.1 The interior purge shall be acceptable for welding when a volume of welding-grade Argon or Helium equal to ten times the volume of the system has passed through the system at a flow rate not to exceed 60 CFH.

NOTE: In all Tacking, 10CFH Argon will be used as a backup.

5.1.2 Internal purge rates shall be reduced to 5 - 20 CFH prior to welding. The exhaust vent from the pipe and cap shall be 3/16" tubing.

5.2 WELD PREPARATION

5.2.1 The edges or surfaces of the parts to be joined by welding shall be prepared by machining or grinding as shown in Figure 1. The weld area and one inch each side thereof shall be cleaned of all slag, burrs, oil, grease, and dirt to present a clean and substantially smooth surface for welding. Thoroughly clean all foreign material from inside of passages.

5.2.2 Remove all oxides from the weld area prior to laying a tack or bead.

5.2.2.1 Steel - abrasive papers or a stainless steel wire brush are acceptable means for oxide removal.

5.2.2.2 Aluminum - The weld area shall be wire brushed, using a stainless steel brush and wiped with a clean, lint-free cloth saturated with chemically pure Acetone within one hour prior to the start of welding.

5.3 TACK WELDING

5.3.1 Tack spacing will be determined by condition and size of the items being welded. In no case will tacks be over 2-1/2 inches apart.

5.3.2 Tack in sequence per the following diagram:

5.3.3 Tack welds shall be small, and proportionate to the pipe size to retain tack-up position, and made by the same process as the initial root bead, producing a quality weld.

5.3.3.1 Do not 'flame' or 'arc gouge' weld area.

5.3.3.2 Tack welds must be either removed or blended in a manner to prevent entrapment of defects or interruption of the weld pass. Blending of tack welds may be accomplished by using a rotary file or burr.

5.3.3.3 Cracked or improper tacks shall be removed.

- 5.3.3.4 Precautions must be taken at all times to protect the welding wire from dirt, grease, oil, moisture, or other forms of contamination.

5.4 WELDING

- 5.4.1 Establish a purge 5 to 20 CFH or Argon before welding and maintain this purge until a minimum of 3/16 inch or three layers of weld have been deposited. Purging may be then discontinued unless a level of cleanliness is required and must be maintained.

NOTE: NOT APPLICABLE TO MANUAL SHIELDED ARC PROCESS.

- 5.4.2 Deposit all welding passes in the same sequence as the tacks. The number of weld increments will be determined by the pipe size. The length of the weld deposits (increments) should not exceed 3 inches for pipe over 6 inch diameter and 2 inches for pipe less than 6 inch diameter to eliminate distortion, and changes in physical properties of the base material.

- 5.4.3 Stagger the starts and ends of increments to avoid start and stop occurrences in the same area through the depth of the joint.

- 5.4.4 Whenever the material temperature is below 60°F., preheat prior to welding. Steel and Invar - 60°F.

Aluminum - 120 - 150°F.

- 5.4.5 Do not exceed interpass temperatures specified for each type of weld. Tempilsticks or equivalent measuring crayons may be used after each pass to check the temperature of the base metal. Apply the tempilstick to the base metal adjacent to the weld.

- 5.4.6 Thoroughly clean oxides of each completed bead or layer with a stainless steel wire brush and wipe with a suitable solvent.
- Steel and Invar - Reagent grade MEK
- Aluminum - Chemically pure Acetone
- 5.4.7 Remove all extraneous weld material from the weld surface before laying down the next bead or layer.
- 5.4.7.1 The torch should be held such that the electrode is on a radius line at all times.
- 5.4.7.2 Intermediate arc stops are to be made by reversing the movement of the torch. Restart overlap for the root pass shall be $3/4$ " to 1" in length.
- 5.4.8 Visually inspect and remove any cracks or blowholes that appear on the welding surface before restarting an arc and also at the completion of the weld.
- 5.4.9 Observe drawing or applicable specifications requiring Nondestructive testing of tacks, root passes or completed welds.
- 5.4.9.1 The root pass on all welds in piping 8 inches in diameter or larger whose thickness is schedule 160 or greater shall be radiographed if radiography is required for the completed weld.

5.5 SPECIFIC TYPE WELDS, METHODS OF

- 5.5.1 Stainless Steel/Gas Tungsten Arc with 'Y' Rings
Proceed per Section I
- 5.5.2 Stainless Steel/Gas Tungsten Arc with Root Gap
Proceed per Section II
- 5.5.3 Stainless Steel/Manual Shielded Metal Arc
Proceed per Section III
- 5.5.4 Carbon Steel/Gas Tungsten Arc with 'Y' Rings.
proceed per Section IV
- 5.5.5 Carbon Steel/Gas Tungsten Arc with Root Gap
Proceed per Section V
- 5.5.6 Carbon Steel/Manual Shielded Metal Arc with Root Gap
Proceed per Section VI
- 5.5.7 Aluminum/Gas Tungsten Arc
Proceed per Section VII
- 5.5.8 Aluminum/Gas Metal Arc
Proceed per Section VIII
- 5.5.9 Invar/Gas Tungsten Arc with Root Gap
Proceed per Section IX
- 5.5.10 Invar to Stainless/Gas Tungsten Arc with Root Gap.
Proceed per Section X
- 5.5.11 Carbon Steel to Austenitic Stainless Steel/Gas Tungsten
Arc with Root Gap
Proceed per Section XI
- 5.5.12 Carbon Steel to Austenitic Stainless Steel/Manual
Shielded Metal Arc with Root Gap.
Proceed per Section XII

6.0 REPAIR

6.1 Remove weld defects per 6.1.1 or 6.1.2 as applicable.

6.1.1 Steel - Defects shall be removed by using a small rotary file or by grinding providing this operation does not include breaking completely through the weld into the inside of the pipe.

6.1.2 Aluminum - Defects shall be removed by filing or chipping without breaking through the weld into the pipe.

6.2 The reworked area shall be liquid dye penetrant inspected per NTO-QCS-107 to insure complete removal of the defect. If this inspection reveals the continued presence of the defect, step 6.1 shall be repeated.

6.3 Remove all dye penetrant and developer per 6.3.1 or 6.3.2 as applicable.

6.3.1 Steel and Invar - Wipe with clean, lint-free cloth saturated in reagent-grade MEK.

6.3.2 Aluminum - Wipe with clean, lint-free cloth saturated in chemically pure acetone.

6.4 Where complete removal of defects can be accomplished and still meet the requirements of step 6.1, the second weld pass may be made directly over the reworked area.

6.5 Where complete removal of the defect cannot be accomplished without breaking through the inside surface of the weld, the defect will be recorded on an inspection report; and NTO and Source Engineering will be contacted for resolution of the problem.

-A-

butt joints without backing rings
for horizontal fixed and vertical
fixed positions

-B-

butt joints with backing rings for
horizontal rolled position only

-C-

butt joints with backing rings for
vertical fixed position

-D-

butt joints with backing rings for
horizontal fixed position

FIGURE 1 Edge Preparation

FIGURE 2 Edge Preparation

FIGURE 3 Location of "Y" Ring

Material Thickness		Without Backing Ring		With Backing Ring
$1/8" \pm 1/16"$		1-2 passes 60 - 110 amps 1/8" electrode 1/8" filler wire		1-2 passes 70-120 amps 1/8" electrode 1/8" filler wire
$1/4" \pm 1/16"$		3-5 passes 120-180 amps 1/8" electrode 5/32" filler wire		3-5 passes 140-200 amps 1/8" electrode 5/32" filler wire
$3/8" \pm 1/16"$		5-7 passes 180-220 amps 5/32" electrode 5/32" filler wire		5-8 passes 23-270 amps 5/32" electrode 5/32" filler wire
$1/2" \pm 1/16"$		7-11 passes 220-240 amps 3/16" electrode 3/16" filler wire		7-11 passes 230-280 amps 3/16" electrode 1/16" filler wire
$5/8" \pm 1/16"$		7-11 passes 220-250 amps 3/16" electrode 3/16" filler wire		7-11 passes 230-280 amps 3/16" electrode 3/16" filler wire
$3/4" \pm 1/16"$		13-18 passes 220-250 amps 3/16" electrode 3/16" filler wire		13-18 passes 230-280 amps 3/16" electrode 3/16" filler wire

FIGURE 4 Mean Amperage Values

<u>Material Thickness</u>	<u>Without Backing Ring</u>	<u>With Backing Ring</u>
1/8"	1-2 passes	1-2 passes
± 1/16"	60-100 amps	70-120 amps
	1/8" electrode	1/8" electrode
	1/8" filler wire	1/8" filler wire
1/4"	2 passes	2 passes
± 1/16"	100-150 amps	120-130 amps
	1/8" electrode	1/8" electrode
	1/8" filler wire	1/8" filler wire
3/8"	2-3 passes	2-3 passes
± 1/16"	150-190 amps	180-250 amps
	5/32" electrode	5/32" electrode
	5/32" filler wire	5/32" filler wire
1/2"	3-5 passes	3-5 passes
± 1/16"	190-210 amps	200-270 amps
	3/16" electrode	3/16" electrode
	3/16" filler wire	3/16" filler wire
5/8"	5-7 passes	5-7 passes
± 1/16"	190-210 amps	200-270 amps
	3/16" electrode	3/16" electrode
	3/16" filler wire	3/16" filler wire
3/4"	7-10 passes	7-10 passes
± 1/16"	190-210 amps	200-270 amps
	3/16" electrode	3/16" electrode
	3/16" filler wire	3/16" filler wire

FIGURE 5 Mean Amperage Values

FIGURE 6 Test Weld For Equipment Check

SECTION I

5.6 Gas Tungsten Arc Butt Welding in conjunction with 'Y' Type consumable inserts for 300 Series Stainless Steel.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 The 'Y' Ring Insert shall be made of a material compatible with both the base material and the filler material.

5.6.2.1 The 'Y' Ring Insert shall be cleaned of all oxides by methods described in section 5.2.2, prior to tack welding.

5.7 TACK WELDING OF 'Y' RING INSERT

5.7.1 Tack welding of the 'Y' Ring Insert is not required if the insert is a pre-formed solid ring and the joint can be clamped in position.

5.7.2 Where tack welds are used, the fusion of the insert arm to the bevel is sufficient. A tack weld spacing of 2 - 4 inches is adequate. All tack welds shall be made on the outside of the part.

5.7.3 Locate the 'Y' ring on one side of joint as shown in Figure 3. Then tack weld as per 5.7.2. Rings over 1/2" in diameter are rolled with an overlap. Tack to first assembly section to within a few inches of overlap then secure the overlap with a vice-grip pliers and saw completely through the side-by-side insert sections. This

NTO-S-0035
Section I

will leave a gap the width of the saw blade which is to be bridged with weld rod after the interior purge is complete and prior to starting the weld. Locate the second half of the assembly in its proper position, and tack weld using a slight offset sequence from the first set of tacks.

5.8 ALIGNMENT

- 5.8.1 The outward inclined arms of the "Y" Ring Insert creates a double-cup effect with the assembly becoming self-aligning.
- 5.8.2 In cases where there is local misalignment between the two pipes which are to be welded, the insert arm may be pushed into position.
- 5.8.3 Where large misalignment gaps exist, it is necessary that filler metal be added simultaneously with reduction of the insert. The filler rod is held in contact with the inset vee of the "Y" Ring Insert and allowed to enter the weld puddle without rod movement as the arc advances.

5.9 ROOT WELDS

- 5.9.1 Interpass temperature must not exceed 350°F.
- 5.9.2 Prior to starting the root pass, a 1/2" long weld should be started 180° from the point the weld bead is to be started. If the weld is not to be started immediately, a second 1/2" long weld should be made at the starting point (180° from the first 1/2" long weld).
- 5.9.3 Vertical welds (pipe in the horizontal plane) shall be started at the bottom of the pipe and proceed towards the top.

NTO-S-0035
Section I

- 5.9.4 Advancement of the torch is determined by breakdown of the Vee formed by inclined arms of the insert. As the arms are melted and drawn into the crater, there is a "wetting action" up the beveled sides. The molten weld surface becomes slightly concave as the root-pass fusion is established.
- 5.9.5 Torch movement should be in a forward direction of travel. Side movement or weaving shall not exceed the width of the "Y" Ring Insert.
- 5.9.6 The suggested weld setup is as follows:
- Welding current: 65/75 amps DCSP 10-15 volts
 - Arc length: 1/8 inch
 - Welding speed: 4-6 IPM (Manual)
- 5.9.7 This procedure requires tungsten inert gas (TIG) welding of filler passes.

NTO-S-0035
Section I

TABLE I

WELDING SPECIFICATION FOR STAINLESS STEEL .100 INCH THICK AND THICKER
USING THE GAS TUNGSTEN ARC PROCESS WITH "Y" RINGS

Applicable Materials (Not all inclusive):

<u>Base Material</u>	<u>Filler Material</u>
	MIL-R-5031
304 to 304	308
304L to 304L or 304	308ELC
316 to 316, 304L or 304	316
316L to 316L, 316, 304L or 304	316ELC
321 to 321	349
347 to 347, 316L, 316, 304L or 304	349

General Parameters:

Thickness	.100" and thicker
Weld prep level angle	37-1/2 degrees, approx.
Weld prep land	1/32" max.
Consumable Insert	"Y" Ring
Root Gap	None
Rod	3/32", 1/8" filler metal
Amperage	Root pass 65/75 Filler passes 65/175
Voltage	12/18
Shield Gas	16/22 CFH Argon
Purge Gas	5/20 CFH Argon
Tungsten electrode	3/32, round 2% thoriated

SECTION II

5.6 Gas Tungsten Arc Built Welding of 300 Series Stainless Steel with a Root Gap.

5.6.1 Paragraphs 1.0 through 5.0 are an integral part of this procedure.

5.6.2 Consumable Inserts, backing rings, or similar items will not be used.

5.6.3 Interpass temperature must not exceed 360°F.

NTO-S-0035
Section II

TABLE I

WELDING SPECIFICATION FOR STAINLESS STEEL .100 INCH THICK AND THICKER
USING THE GAS TUNGSTEN ARC PROCESS

Applicable Materials (Not all inclusive):

<u>Base Material</u>	<u>Filler Material</u>
	MIL-R-5031
304 to 304	308
304L to 304L or 304	308ELC
316 to 316, 304L or 304	316
316L to 316L, 316, 304L or 304	316ELC
321 to 321	349
347 to 347, 316L, 316, 304L or 304	349

General Parameters:

Thickness	.100" and over
Weld prep., land	1/16" ± 1/32"
Root gap	1/16" ± 1/32"
Rod	1/16", 3/32", 1/8" type same as filler metal
Amperage	Root pas - 65/85 Filler passes - 65/175
Voltage	12/18
Shield gas	16/22 CFH Argon
Purge Gas	5/20 CFH Argon
Tungsten electrode	3/32", round; 2% thoriated

SECTION III

5.6 Manual Shielded Metal Arc Butt Welding of 300-Series Stainless Steel.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 Consumable inserts, backing rings or similar items will not be used.

5.6.3 Interpass temperature must not exceed 350°F.

5.6.4 The root pass on all piping shall be made using the Gas Tungsten Arc welding process.

NTO-S-0035
Section III

TABLE I

WELDING SPECIFICATION FOR STAINLESS STEEL .100 INCH AND THICKER

USING THE GAS TUNGSTEN ARC PROCESS

Applicable Materials: (Not all inclusive)

<u>Base Material</u>	<u>Filler Material</u>	
	<u>Root Passes</u>	<u>Filler Passes</u>
	MIL-R-5031	MIL-E-22200/2
304 to 304	308	308
304L to 304L or 304	308ELC	308L
316 to 316, 304L or 304	316	316
347 to 347, 316L, 316, 304L or 304	349	349

General Parameters

Thickness	.100" and over
Weld prep bevel angle	37-1/2 degrees, approx.
Weld prep land	1/32" min., 3/64" max.
Root gap	1/16" $\pm$ 1/32"
Rod	1/8", 5/32", 3/16"
Amperage	Root pass - 80 - 105 3/16" - 125-175 5/32" - 100-140
Voltage	12/18
D.C. Reverse polarity current shall be used. The base metal shall be on the negative side of the line.	
Shield gas	16/22 CFH Argon
Purge gas	5/20 CFH Argon
Tungsten electrode	3/32", round 2% thoriated

SECTION IV

5.6 Gas Tungsten Arc Welding in conjunction with "Y" Type consumable inserts using Carbon Steel.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 The "Y" Ring Insert shall be made of a material compatible with both the base material and the filler material.

5.6.2.1 The "Y" Ring Insert shall be cleaned of all oxides by methods described in section 5.2.2, prior to tack welding:

5.7 TACK WELDING OF "Y" RING INSERT

5.7.1 Tack welding of the "Y" Ring Insert is not required if the insert is a pre-formed solid ring and the joint can be clamped in position.

5.7.2 Where tack welds are used, the fusion of the insert arm to the bevel is sufficient. A tack weld spacing of 2 - 4 inches is adequate. All tack welds shall be made on the outside of the part.

5.7.3 Locate the "Y" ring on one side of joint as shown in Figure 3. Then tack weld as per 5.7.2. Rings over 1/2" in diameter are rolled with an overlap. Tack to first assembly section to within a few inches of overlap then secure the overlap with a vice-grip pliers and saw completely through the side-by-side insert sections. This will leave a gap the width of the saw blade which

NTO-S-0035
Section IV

is to be bridged with weld rod after the interior purge is complete and prior to starting the weld. Locate the second half of the assembly in its proper position, and tack weld using a slight offset sequence from the first set of tacks.

5.8 ALIGNMENT

- 5.8.1 The outward inclined arms of the "Y" Ring Insert creates a double-cup effect with the assembly becoming self-aligning.
- 5.8.2 In cases where there is local misalignment between the two pipes which are to be welded, the insert arm may be pushed into position.
- 5.8.3 Where large misalignment gaps exist, it is necessary that filler metal be added simultaneously with reduction of the insert. The filler rod is held in contact with the inset vee of the "Y" Ring Insert and allowed to enter the weld puddle without rod movement as the arc advances.

5.9 ROOT WELDS

- 5.9.1 Interpass temperature must not exceed 350°F.
- 5.9.2 Prior to starting the root pass, a 1/2" long weld should be started 180° from the point the weld bead is to be started. If the weld is not to be started immediately, a second 1/2" long weld should be made at the starting point (180° from the first 1/2" long weld).
- 5.9.3 Vertical welds (pipe in the horizontal plane) shall be started at the bottom of the pipe and proceed towards the top.

NTO-S-0035
Section IV

- 5.9.4 Advancement of the torch is determined by breakdown of the Vee formed by inclined arms of the insert. As the arms are melted and drawn into the crater, there is a "wetting action" up the beveled sides. The molten weld surface becomes slightly concave as the root-pass fusion is established.
- 5.9.5 Torch movement should be in a forward direction of travel. Side movement or weaving shall not exceed the width of the "Y" Ring Insert.
- 5.9.6 The suggested weld setup is as follows:
- Welding current: 65/75 amps DCSP 10-15 volts
 - Arc length: 1/8 inch
 - Welding speed: 4-6 IPM (Manual)
- 5.9.7 This procedure requires tungsten inert gas (TIG) welding of filler passes.

NTO-S-0035
Section IV

TABLE I

HEAT TREATMENT

Stress relief requirements shall be in accordance with ASME, Sec. VIII, Subsection C, Part USC56.

WELDING SPECIFICATION FOR CARBON STEEL WITH .100 INCH THICK AND HEAVIER,
USING THE GAS TUNGSTEN ARC PROCESS WITH CONSUMABLE INSERT

Applicable Materials

<u>Base Material</u>		<u>Filler Material</u>
SA-53	SA-192	MIL-R-5632
SA-83	SA-210	E7018
SA-106	SA-214	
SA-135	SA-226	
SA-178	SA-333	
SA-179	SA-334	

General Parameters

Thickness	.100" and over
Weld prep bevel angle	37-1/2 degrees, approx.
Weld prep land	1/23" min., 1/32"
Consumable inert	1/8", 5/32", type 131
Root gap	None
Rod	3/32", 1/8" type same as filler metal
Amperage	Root pass - 65/85 Filler passes - 65/175
Voltage	12/18
Shield gas	16/22 CFH Argon
Purge gas	5/20 CFH Argon
Tungsten electrode	3/32", round, 2% thoriated

NOTE: Carbon steel inserts and TIG wire have an oil base coating to prevent rust - this coating must be completely removed by use of degreasing solvent prior to welding.

SECTION V

5.6 Gas Tungsten Arc Welding on Steels "Other Than" Stainless Steel with a Root Gap.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 Consumable inserts, backing rings, or similar items will not be used.

5.6.3 Interpass temperature must not exceed 360°F.

5.6.4 Small stringer beads using low heat input will be used.

5.6.5 The welding speeds will be kept low to minimize porosity.

NTO-S-0035
Section V

TABLE I

HEAT TREATMENT

Stress relief requirements shall be in accordance with ASME, Sec. VIII, Subsection C, Part USC 56.

WELDING SPECIFICATION FOR CARBON STEEL WITH .100 INCH THICKNESS AND OVER, USING THE GAS TUNGSTEN ARC PROCESS

Applicable Materials

<u>Base Material</u>		<u>Filler Material</u>
		MIL-R-5632
SA-53	SA-193	E-7018
SA-83	SA-210	
SA-106	SA-214	
SA-135	SA-226	
SA-178	SA-333	
SA-179	SA-334	

General Parameters

Thickness	.100" and over
Weld prep bevel angle	37-1/2 degrees, approx.
Weld prep land	1/32" min., 3/64" max.
Root gap	1/16", 1/8"
Rod	1/16", 3/32", 1/8" type same as filler metal
Amperage	Root pass - 65/85 Filler passes - 65/175
Voltage	12/18
Shield gas	16/22 CFH Argon
Purge gas	5/20 CFH Argon
Tungsten electrode	3/32", round, 2% thoriated

NOTE: Carbon steel wire has an oil-base coating to prevent rust - this coating must be completely removed prior to welding by wiping with a degreasing solvent.

SECTION VI

5.6 Manual Shielded Metal Arc Butt Welding of Steels "Other Than"
Stainless Steel with a Root Gap.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this
procedure.

5.6.2 Consumable inserts, backing rings, or similar items
will not be used.

5.6.3 Interpass temperature must not exceed 350°F.

5.6.4 The root pass on all piping shall be made using the
Gas Tungsten Arc welding process.

NTO-S-0035
Section VI

TABLE I

HEAT TREATMENT

Stress relief requirements shall be in accordance with ASME Sec. VIII, Subsection C, Part UCS-56.

WELDING SPECIFICATION FOR CARBON STEEL .100 INCH AND THICKER

USING THE MANUAL SHIELDED METAL ARC PROCESS

Applicable Materials

Base Material

SA-53 SA-192
SA-83 SA-210
SA-106 SA-214
SA-135 SA-226
SA-178 SA-333
SA-179 SA-334

Filler Material

MIL-E-22200/1
E-7018

General Parameters

Thickness	.100" and thickness
Weld prep bevel angle	37-1/2 degrees, approx.
Weld prep land	1/32" min., 3/64" max.
Root gap	1/16 ± 1/32"
Rod size	1/8", 5/32", 3/16"
Amperage	1/8", 70 - 130 5/32", 110 - 165 3/16", 140 - 225
Voltage	12 - 40
D. C. Reverse polarity current shall be used. The base metal shall be on the negative side of the line.	
Amperage	Root Pass - 65/85
Voltage	12/18
Shield Gas	16/22 CFH Argon
Purge Gas	5/20 CFH Argon
Tungsten Electrode	3/32", Round, 2% Thoriated

SECTION VII

5.6 Gas Tungsten Arc Welding on Aluminum.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 Interpass temperature must not exceed 300°F.

5.7 BASE METAL

5.7.1 The base metal will conform to the applicable requirements of P number groups 21, 22, 23, and 24. See Table 1 of this Section.

5.8 FILLER METAL

5.8.1 The filler metal will be annealed bare wire conforming to one of the F numbers 21 through 23 as specified in Table 1 of this section.

NOTE: Filler metal having no F number will be qualified as a separate procedure. Filler material shall comply with MIL-E-16053.

5.9 SHIELDING MEDIA

5.9.1 Argon, helium or a mixture of argon and helium gas will be used as a shield.

5.10 The number of passes, electrode diameter and filler metal for each pass, and mean amperage values for each pass are specified in Figure 4 and 5 for each joint thickness.

5.10.1 Apply weld metal to avoid undercutting the weld groove or the adjoining material. Deposit a weld reinforcement of 1/16 to 1/8 inch with a smooth gradual increase in thickness from the edge to the center of the weld.

NTO-S-0035
Section VII

- 5.10.2 When the parent material thickness is 1/4 inch or over,
a preheat of 150°F., maximum, shall be used.

NTO-S-0035
Section VII

TABLE I

FILLER MATERIAL FOR VARIOUS ALUMINUM ALLOYS

<u>Base Material</u>	<u>P Number</u>	<u>Filler Alloy</u>	<u>F Number</u>
1100	21	1100	21
1100	21	4043	23
3003	21	1100	21
3003	21	4043	23
3003	21	5183	22
5050	21	1100	21
5050	21	4043	23
5050	21	5154	22
5050	21	5183	22
5050	21	5356	22
5052	22	5154	22
5052	22	5183	22
5154	22	4043	23
5154	22	5154	22
5154	22	5183	22
5154	22	5356	22
5083	24	1100	21
5083	24	5154	22
5083	24	5183	22
5083	24	5356	22
5086	22	5154	22
5086	22	5183	22
5086	22	5356	22
6061	23	1100	21
6061	23	4043	23
6061	23	5154	22
6061	23	5356	22
6061	23	5556	22

SECTION VIII

5.6 Gas Metal Arc Welding on Aluminum

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 Base Metal

5.6.2.1 The base metal will conform to the applicable requirements of P number groups 21, 22, 23 and 24, as shown in Table I of this Section.

5.7 FILLER METAL

5.7.1 The filler metal will be annealed bare wire conforming to one of the F numbers 21 through 23.

5.7.1.1 Filler metal having no F number will be qualified as a separate procedure.

5.7.1.2 Filler material shall comply with MIL-E-16053.

5.8 SHIELDING MEDIA

5.8.1 Argon gas will be used as a shield. An inert atmosphere (outside the shield) is not necessary. A mixture of helium and argon may be used providing the helium does not exceed 75% of the mixture.

5.9 WELDING

5.9.1 Preheat

5.9.1.1 When the parent material thickness is 1/4 inch or greater, a preheat of 150°F., maximum shall be used. The welding machine, complete with the welding torch and accessories, shall be checked at the following times to insure equipment is functioning properly:

NTO-S-0035
Section VIII

- (a) At the start of each working shift.
- (b) Whenever a maintenance change in equipment or accessories is required.
- (c) Whenever the wire spool is changed.

5.9.1.2 The weld equipment check shall consist of welding and testing a sample joint as described in Figure 6. In order to be considered acceptable, the weld shall have a uniform and clean surface appearance; and the fractured face (except for 1/2 inch at each end) shall have no unfused areas, entrapped oxides or excessive porosity.

5.9.1.3 Direct current, reverse polarity, shall be used. Recommended amperage and voltage for various base metal thicknesses are listed in Table II.

5.9.1.4 High purity welding grade Argon shall be used. Smooth wire drive rolls are required for aluminum wire. The flexible conduit supporting the wire between the drive rolls and the torch shall be equipped with a nylon insert liner to provide smooth wire feeding. Periodic replacement of the liner, as wear takes place, is required.

NTO-S-0035
Section VIII

- 5.9.1.5 String beads or slightly weaving beads are preferred, with the maximum width of the weld deposit to be approximately ten times the diameter of the welding wire being used.
- 5.9.1.6 In multipass welds, each pass must be wire brushed, using a stainless steel brush in accordance with Section 5.2
- 5.9.1.7 Weld pass starts and finish craters shall be examined with a 10 X glass and blended to remove all defects. Interpass temperature must not exceed 300°F.

MT0-S-0035
Section VIII

TABLE I

FILLER MATERIAL FOR VARIOUS ALUMINUM ALLOYS

<u>Base Material</u>	<u>P Number</u>	<u>Filler Alloy</u>	<u>F Number</u>
1100	21	1100	21
1100	21	4043	23
3003	21	1100	21
3003	21	4043	23
3003	21	5183	22
5050	21	1100	21
5050	21	4043	23
5050	21	5154	22
5050	21	5183	22
5050	21	5356	22
5052	22	5154	22
5052	22	5183	22
5052	22	5356	22
5154	22	4043	23
5154	22	5154	22
5154	22	5183	22
5154	22	5356	22
5083	24	1100	21
5083	24	5154	22
5083	24	5183	22
5083	24	5356	22
5086	22	5154	22
5086	22	5183	22
5086	22	5356	22
6061	23	1100	21
6061	23	4043	23
6061	23	5154	22
6061	23	5356	22
6061	23	5556	22

NTO-S-0035
Section VIII

TABLE II

Plate Thickness	Welding Voltage		Welding Amperage		Argon Flow Cubic Ft/H
	3/64" Wire	1/16" Wire	3/64" Wire	1/16" Wire	
1/8	20 - 22	22 - 24	120 - 140	170 - 190	35 - 40
3/16	22 - 24	24 - 26	140 - 170	190 - 220	40 - 50
1/2	24 - 26	25 - 27	170 - 210	220 - 260	50 - 55
5/8	25 - 27	26 - 28	170 - 210	220 - 260	50 - 55
3/4 & Over	25 - 27	27 - 30	170 - 210	220 - 260	55 - 60

SECTION IX

- 5.6 Gas Tungsten Arc Butt Welding of Invar with a Root Gap
 - 5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.
 - 5.6.2 Consumable Inserts, backing rings or similar items will not be used.
 - 5.6.3 Interpass temperature must not exceed 360°F.
 - 5.6.4 Small stringer beads using low heat input will be used.
 - 5.6.5 The welding speeds will be kept low to minimize porosity.

WFO-S-0035
Section IX

TABLE I
WELDING SPECIFICATION FOR INVAR .100 INCH THICK AND HEAVIER
USING THE GAS TUNGSTEN ARC PROCESS

<u>Applicable Materials</u>		
<u>Base Material</u>	<u>Filler Material</u>	
Iron - 36 percent nickel	Modified Invar Wire	
a. Chemical Composition of Filler Wire		
<u>Element</u>	<u>Aim</u>	<u>Range %</u>
Ni	36.00	34 to 38
C	0.10	0.08 to 0.15
Si	0.25	0.25 Max.
Mn	3.00	2.2 to 3.5
Al	0.07	0.07 added
Ti	1.00	0.05 to 1.5
P	Low	0.01
Pb	Low	0.01
S	Low	0.02
O	Low	0.010 Max.
Ca	0.05	0.05 added
Fe	Bal.	Bal.

<u>General Parameters</u>	
Thickness	.100" and over
Weld prep., land	1/32" min., 3/32" max.
Root gap	1/16" $\pm$ 1/32"
Rod	1/16", 3/32", 1/8" type same as filler metal
Amperage	Root pass - 35/40 Filler passes - 70/90
Voltage	12/18
Shield Gas	16/22 CFH Argon
Purge gas	5/20 CFH Argon
Tungsten electrode	3/32", round 2% thoriated

SECTION X

5.6 Gas tungsten Arc Butt Welding of Invar to Stainless Steel with a Root Gap.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 Consumable inserts, backing rings, or similar items will not be used.

5.6.3 Interpass temperature must not exceed 360°F.

5.6.4 Small stringer beads using low heat input will be used.

5.6.5 The welding speeds will be kept low to minimize porosity.

MTO-S-0035
Section X

TABLE I

WELDING SPECIFICATION FOR INVAR TO STAINLESS STEEL .100 INCH THICK
AND HEAVIER USING THE GAS TUNGSTEN ARC PROCESS

Applicable Materials

<u>Base Material</u>		<u>Filler Material</u>
Iron - 36 percent nickel		Modified Invar Wire
a. Chemical composition of Filler Wire		
<u>Element</u>	<u>Aim</u>	<u>Range %</u>
Ni	36.00	34 to 38
C	0.10	0.08 to 0.15
Si	0.25	0.25 Max.
Mn	3.00	2.2 to 3.5
Al	0.07	0.07 added
Ti	1.00	0.5 to 1.5
P	Low	0.01
Pb	Low	0.01
S	Low	0.02
O	Low	0.010 Max.
Ca	0.05	0.05 added
Fe	Bal.	Bal.

General Parameters

Thickness	.100" and over
Weld prep., land	1/32" min., 3/32" max.
Root gap	1/16" $\pm$ 1/32"
Rod	1/16", 3/32", 1/8" type same as filler metal
Amperage	Root pass - 35/40 Filler pass - 70/130
Voltage	12-18
Shield gas	16-22 CFH Argon
Purge gas	5-20 CFH Argon
Tungsten electrode	3/32", round 2% thoriated

SECTION XI

5.6 Gas Tungsten Arc Butt Welding of Carbon Steel to Stainless Steel with a Root Gap.

5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.

5.6.2 Consumable inserts, backing rings, or similar items will not be used.

5.6.3 Interpass temperature must not exceed 360°F.

5.6.4 Attach all purge connections and purge the internal area with 20 CFH Argon for a minimum of 5 minutes.

NOTE: In all tacking, 10 CFH Argon will be used as a backup.

5.6.5 Small stringer beads using low heat input will be used.

5.6.6 The welding speeds will be kept low to minimize porosity.

NTO-S-0035
Section XI

TABLE I

HEAT TREATMENT

Stress relief requirements shall be in accordance with ASME Sec. VIII Subsection C, Part UCS 56.

WELDING SPECIFICATION FOR CARBON STEEL TO STAINLESS STEEL .100 INCH
AND THICKER USING THE GAS TUNGSTEN ARC PROCESS

<u>Applicable Materials</u>		
<u>Base Material</u>		<u>Filler Material</u>
<u>Carbon Steel</u>	<u>Stainless Steel</u>	Mil-R-5031
SA-53	304	
SA-83	304L	310
SA-106	316	
SA-135	316L	
SA-178	347	
SA-179		
SA-192		
SA-210		
SA-214		
SA-226		
SA-333		
SA-334		
SA-105		
SA-181		
SA-216		
SA-352		

NTQ-S-0035
Section XI

TABLE II

General Parameters

Thickness	.100" wall and over
Weld Prep Bevel Angle	37-1/2 degrees approx.
Weld Prep Land	1/32" min., 3/64" max.
Root Gap	1/16", 1/8"
Rod	1/16", 3/32", 1/8" type same as filler metal
Amperage	Root pass - 65/85 Filler pass - 65/175
Voltage	12 - 18
Shield gas	16 - 22 CFH Argon
Purge gas	5 - 20 CFH Argon
Tungsten Electrode	3/32", round, 2% thoriated

ALTERNATE METHOD FOR WELDING CARBON STEEL TO STAINLESS STEEL .100 INCH
AND THICKER USING THE GAS TUNGSTEN ARC PROCESS

It is permissible to use the technique of "buttering" the carbon steel joint face with the E 310 weld wire and then using the appropriate stainless steel weld wire as shown:

Applicable Materials

<u>Stainless Steel</u>	<u>Filler Material</u>
	Mil-R-5031
304	308
304L	308 ELC
316	316
316L	316 ELC
347	349

SECTION XII

- 5.6 Manual Shielded Metal Arc Butt Welding of Carbon Steel to Stainless Steel with a Root Gap.
- 5.6.1 Paragraphs 1.0 through 5.5 are an integral part of this procedure.
- 5.6.2 Consumable inserts, backing rings, or similar items will not be used.
- 5.6.3 Interpass temperature must not exceed 360°F.
- 5.6.4 Attach all purge connections and purge the internal area with 15 CFH Argon for a minimum of 5 minutes.
- NOTE: In all tacking, 10 CFH Argon will be used as a backup.
- 5.6.5 Small stringer beads using low heat input will be used.
- 5.6.6 The welding speeds will be kept low to minimize porosity.

NTO-S-0035
Section XII

TABLE I

HEAT TREATMENT

Stress relief requirements shall be in accordance with ASME Sec. VIII, Sub-section C, Part UCS 56.

WELDING SPECIFICATION FOR CARBON STEEL TO STAINLESS STEEL .100 INCH
AND THICKER USING THE MANUAL SHIELDED METAL ARC PROCESS

Applicable Materials

<u>Base Material</u>		<u>Filler Material</u>
<u>Carbon Steel</u>	<u>Stainless Steel</u>	Nil-E-22200/2
SA-53	304	310
SA-83	304L	310
SA-106	316	310
SA-135	316L	310
SA-178	347	310
SA-179		310
SA-192		310
SA-210		310
SA-214		310
SA-226		310
SA-333		310
SA-334		310
SA-105		310
SA-181		310
SA-216		310
SA-352		310

NTO-S-0035
Section XII

TABLE II

General Parameters

Thickness	.100 thickness and over
Weld Prep Bevel Angle	37-1/2 degrees - approx.
Weld Prep Land	1/32" min., 3/4" max.
Root Gap	1/16" - 1/8"
Rod Size	1/8", 5/32", 3/16"
Amperage	(1/8") 70-120 (5/32") 100-150 (3/16") 120-200
Voltage	12 - 35

D. C. Reverse polarity current shall be used. The base metal shall be on the negative side of the line.

ALTERNATE METHOD FOR WELDING CARBON STEEL TO STAINLESS STEEL .100 INCH
AND THICKER USING THE MANUAL SHIELDED METAL ARC PROCESS

It is permissible to use the technique of "buttering" the carbon steel joint face with the E 310 weld wire and then using the appropriate stainless steel weld wire as shown:

Applicable Materials

<u>Stainless Steel</u>	<u>Filler Material</u>
	Mil-E-22200/2
304	308
304L	308ELC
316	316
316L	316ELC
347	347