(5) Undercut shall not exceed 0.15 times the thickness of the test weldment base metal.

After visual examination, the test weldment(s) shall be subjected to the same tests required for groove welds in Table 2.1 and shall meet the following requirements for acceptance.

2.12.2.1 Tension test(s) shall demonstrate that the welded joint meets the minimum specified tensile strength of the base metal.

2.12.2.2 Bend tests may be conducted in a test fixture similar to Annex II, Figure(s) II-5A, II-5B, or II-5C, and shall be acceptable if there are no cracks evident in the base metal or weld metal exceeding 1/16 in. after bending. Alternatively bend test(s) may consist of bending the specimen blank back upon itself, with the axis of the bend being parallel to the axis of the weld. Fractures or cracks resulting from bending shall show no evidence of weld related defects.

2.12.3 Completed fillet test weldment(s) shall be visually examined, and except for the first and last 1/2 in. of weld shall meet the following acceptance criteria:

(1) The weld shall have complete fusion.

(2) Undercut shall not exceed 0.15 times the thickness of test weldment(s).

(3) Not more than one visible pore or inclusion exceeding 0.25 of the base metal thickness, shall be permitted in any 1 in. of weld.

(4) The weld shall be free of overlap or cracks.

2.12.4 After visual examination, the fillet test weldment shall be subjected to the tests required for fillet welds in Table 2.1 and shall meet the following requirements:

(1) The macro section specimen shall show complete fusion at the root and be free of cracks.

(2) If not stated in the Referencing Document, the shear test shall demonstrate a shear strength not less than 60% of the lower of the minimum specified base metal tensile strength or of the minimum specified weld metal tensile strength. The shear strength of aluminum welds is listed in Table 2.6.

2.13 Welding Procedure Specification Data

The following matrix indicates the welding data to be included in a WPS for each welding process. A WPS may be presented in any format, written or tabular, provided the data required in this matrix are included (see 2.1.4). The WPS may list variables recorded on the PQR within the full range permitted for a qualification variable and practical limits determined by the employer for other than qualification variables.

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.13.1 Joint Design												
(1) Joint type and dimensions.	X	X	X	X	X	X	X	X	X	X	X	
(2) Treatment of backside, method of gouging/ preparation.	X	X	X	X	X	X	X	X	X	X	X	
(3) Backing material, if used.	X	X	X	X	X	X	X	X	X	X	X	
(4) Size, shape, ferrule/flux type.												X
2.13.2 Base Metal												
(1) M-Number and Group Number.	X	X	X	X	X	X	X	X	X	X	X	X
(2) Thickness range qualified.	X	X	X	X	X	X	X	X	X	X	X	X
(3) Diameter (tubular only).	X	X	X	X	X	X	X	X	X	X	X	X
2.13.3 Filler Metal												
(1) Classification, specification, F- and A-Number, or if not classified the nominal composition.	X	X	X	X	X	X	X	X	X	X	X	
(2) Weld metal thickness by process and filler metal classification.	X	X	X	X	X	X	X					
(3) Filler metal size or diameter.	X	X	X	X	X	X	X	X	X	X	X	
(4) Flux classification.				X				X				
(5) Supplemental filler metal.			X	X	X	X	X	X	X	X	X	
(6) Consumable insert and type.			X				X					
(7) Consumable guide.								X	X			
(8) Supplemental detoxidant.										X	X	

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.13.4 Position												
(1) Welding position(s).	X	X	X	X	X	X	X	X	X	X	X	X
(2) Progression for vertical welding.	X	X	X	X	X	X	X			X	X	
2.13.5 Preheat and Interpass												
(1) Preheat minimum.		X	X	X	X	X	X			X	X	X
(2) Interpass temperature maximum (if applicable).		X	X	X	X	X	X			X	X	
(3) Preheat maintenance.		X	X	X	X	X	X			X	X	
2.13.6 Heat Treatment												
(1) PWHT temperature and time.	X	X	X	X	X	X	X	X	X	X	X	X
2.13.7 Shielding Gas												
(1) Torch shielding gas and flow rate range.			X		X	X	X		X		X	X
(2) Root shielding gas and flow rate range.			X				X					
(3) Fuel gas and flame type (oxidizing, neutral, or reducing).	X											
(4) Environmental shielding and vacuum pressure.										X		
2.13.8 Electrical												
(1) Current (or wire feed speed), current type, and polarity.		X	X	X	X	X	X	X	X	X		X
(2) Voltage range (except for manual welding).			X	X	X	X	X	X	X	X		
(3) Beam focus current pulse frequency range, and filament type, shape and size.										X		
(4) Type and diameter of tungsten electrode.			X				X					
(5) Transfer mode.					X	X						
(6) A change to or from pulsed current.		X	X		X	X	X					
2.13.9 Variables (see 2.14.9)												
(1) Welding process and whether manual, semiautomatic, mechanized, or automatic.	X	X	X	X	X	X	X	X	X	X	X	X
(2) For mechanized or automatic, single or multipass electrode and spacing.			X	X	X	X	X	X	X	X		
(3) Single or multipass.	X	X	X	X	X	X	X	X	X	X	X	
(4) Contact tube to work distance.				X	X	X		X	X			
(5) Cleaning.		X	X	X	X	X	X	X	X	X	X	X
(6) Peening.		X	X	X	X	X	X	X	X			
(7) Conventional or keyhole technique.							X			X	X	
(8) Stud gun model and lift.												X
(9) Standoff distance.							X			X	X	
(10) Backing shoe type.								X	X			
(11) Stringer or weave bead.		X	X	X	X	X	X					
(12) Travel-speed range for mechanized or automatic welding.			X	X	X	X	X	X	X	X	X	

2.14 Procedure Qualification Variables

This matrix lists the procedure qualification variables to be recorded on the PQR for each welding process. A change in a procedure qualification variable requires requalification of the procedure (see 2.1.7). The PQR shall list the values of the actual variables used, within the limits of the range employed. The key to the entries in the body of the table is as follows:

Q—Qualification variable for all applications
T—Qualification variable for toughness applications
C—Qualification variable for weld cladding applications
H—Qualification variable for hardfacing applications

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.14.1 Joint Design												
(1) A change in groove type (V-groove, U-groove, single bevel, etc.										Q	Q	
(2) A change from a fillet to a groove weld.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(3) A change in the M-Number of backing.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(4) The addition of thermal backgouging on M-11, M-23, M-24, M-26, or M-27 heat-treatable base metal.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(5) The addition or deletion of nonmetallic retainers or nonfusing metal retainers.								Q	Q			
(6) The addition or deletion of backing or backing shoes.								Q	Q			
(7) An increase in fit-up gap beyond that used in the qualification test.										Q	Q	
2.14.2 Base Metal												
(1) A change in base metal thickness beyond the range permitted in 2.5.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(2) A change from one M-Number base metal to another M-Number base metal or to a combination of M-Number base metals or to an unlisted base metal, except as permitted in 2.3.10.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
(3) A change from one M-Number Group Number to any other M-Number Group Number, except as permitted in 2.3.11.		T	T	T	T	T	T	T	T	Q	Q	
(4) A change from one M-5 group (A, B, etc.) to any other. A change from M-9A to M-9B, but not vice versa. A change from one M-10 or M-11 group (A, B, etc.) to any other group.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(5) A change from an uncoated metal to a coated (such as painted or galvanized) metal unless the coating is removed from the weld area prior to welding, but not vice versa, except as permitted in 2.3.8.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.14.3 Filler Metals												
(1) A change from one F-Number to any other F-Number or to any filler metal not listed in Annex III.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(2) For ferrous materials, a change from one A-Number to any other A-Number or to a filler metal analysis not listed in Annex III (the PQR and WPS shall state the nominal chemical composition, the AWS classification, or the manufacturer's designation for filler metals which do not fall in an A-Number group). Qualification with A-1 shall qualify for A-2 and vice versa.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(3) For surfacing, a change in the chemical composition of the weld metal (A-Number or alloy type). Each layer shall be considered independent of other layers.	CH	CH	CH	CH	CH	CH	CH	CH				
(4) A change in AWS filler metal classification.	Q	T	T	T	T	T	T	T	T	T	Q	
(5) A change in filler metal tensile strength exceeding 10 000 psi, or a change in filler metal classified to a strength lower than the specified minimum ultimate tensile strength of the base metal.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q		
(6) If the weld metal alloy content is largely dependent upon the composition of the flux, any change in the welding procedure which would result in the important weld metal alloying elements being outside the specified chemical composition range of the WPS.				Q				Q				
(7) A change in the cross-sectional area of filler metal added (excluding buttering) of ±10%.										Q	Q	
(8) The addition or deletion of filler material.			Q				Q			Q	Q	
(9) A decrease in thickness or a change in the nominal chemical composition of surfacing or buttering beyond that qualified.	CH	CH	CH	CH	CH	CH	CH	CH		CH	CH	
(10) A change of filler metal/electrode nominal size/shape in the first layer.		CH		CH	CH	CH						
(11) Addition or deletion of supplementary filler metal (powder or wire), or a change of 10% in the amount.	Q	T	T	Q	Q	T	Q	T	T	T	Q	
(12) A change from single to multiple supplementary filler metal or vice versa.	CH		CH	CH	CH	CH	CH					
(13) A change from consumable guide to nonconsumable guide, and vice versa.								Q				

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.14.3 Filler Metals (Cont'd)												
(14) Addition or deletion, or a change in the nominal amount or composition of supplementary metal (in addition to filler metal) beyond that qualified.				Q	Q				Q			
(15) A change from wire to strip electrodes and vice versa.				Q				Q				
(16) A change from one AWS electrode-flux classification listed to any other electrode-flux classification, or to an unlisted electrode-flux classification. A variation of 0.5% of the molybdenum content of the weld metal does not require requalification.				Q				Q				
(17) A change in the weld metal thickness beyond that permitted in 2.5.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	
(18) The addition or deletion, or a change in the nominal amount or composition of supplementary deoxidation material beyond that qualified.										Q	Q	
2.14.4 Position												
(1) A change from any position to the vertical position, uphill progression. Vertical uphill progression qualifies all positions.		T	T		T	T	T					
(2) The addition of a welding position, except that positions other than flat also qualify for flat.	CH	CH	CH	CH	CH	CH	CH					Q
2.14.5 Preheat and Interpass Temperature												
(1) A decrease in preheat of more than 100°F from that qualified.		Q	Q	Q	Q	Q	Q			Q	Q	Q
(2) An increase of more than 100°F in the maximum interpass temperature from that recorded on the PQR.		T	T	T	T	T	T					
(3) For M-23, M-24, M-26 and M-27 heat-treatable materials an increase in the preheat or interpass temperature of more than 100°F from that qualified.		Q	Q		Q		Q					
2.14.6 Postweld Heat Treatment												
(1) For the following M-Numbers 1, 3, 4, 5, 6, 7, 9, 10, 11, and 12, a change from any one condition to any other requires requalification: (a) No PWHT. (b) PWHT below the lower transformation temperature. (c) PWHT within the transformation temperature range.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.14.6 Postweld Heat Treatment (Cont'd)												
(d) PWHT above the upper transformation temperature.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
(e) PWHT above the upper transformation temperature, followed by treatment below the lower transformation temperature.												
(2) For all materials not covered above, a separate PQR is required for no PWHT and PWHT.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
(3) The qualification test weldment shall be subjected to heat treatment essentially equivalent to that of the production weldment, including at least 80% of the aggregate time at temperature.	T	T	T	T	T	T	T	T	T	T		
2.14.7 Shielding Gas												
(1) Addition or deletion of torch shielding gas.			Q		Q	Q	Q		Q		Q	Q
(2) A change in the specified nominal composition of shielding gas.			Q		Q	Q	Q		Q		Q	Q
(3) A change of shielding environment from vacuum to an inert gas.										Q	Q	
(4) An increase in vacuum pressure.										Q		
(5) A change in shielding, as a result of a change in ferrule or flux type.												Q
(6) For M-51, M-52, M-61, and M-10I base metal, a change in the nominal composition or a decrease of 15% in the root shielding flow rate.			Q		Q		Q					
(7) For M-21 through M-27, an increase of 50% or more, or a decrease of 20% or more in the shielding gas flow rate used for qualification.			Q		Q		Q					
(8) The addition, deletion, or a change in composition, or a decrease exceeding 15% in the flow rate of root shielding gas on single-sided M-4X groove joints and for all welds in M-51 through M-54, M-61 and M-62, M-10I, M-10J, and M-10K.			Q		Q		Q					
(9) For M-10I, M-51 through M-54, and M-61 and M-62, the deletion of, or a change in composition of, or a decrease exceeding 10% in the trailing gas flow rate.			Q		Q		Q				Q	
(10) The addition, deletion, a 5% flow rate change for any gas used in the process, or a change in the orientation of the plasma-removing gas jet relative to the workpiece (e.g., coaxial transverse to beam).											Q	

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.14.8 Electrical Characteristics												
(1) An increase in heat input or volume of weld metal deposited per unit length of weld, over that qualified, except when a grain refining austenitizing heat treatment is applied after welding. The increase may be measured by either of the following: (a) Heat input (J/in.) = $\frac{\text{Volts} \times \text{Amps} \times 60}{\text{Travel Speed (in./min)}}$. (b) Weld Metal Volume—An increase in bead size, or a decrease in the length of weld bead per unit length of electrode.		T	T	T	T	T	T	T	T	T	T	
(2) A change exceeding ±2% in the voltage from that qualified.										Q		
(3) A change exceeding ±5% in the beam or beam focus current from that qualified.										Q		
(4) A change in the beam pulsing frequency or duration from that qualified.										Q		
(5) A change in filament type, size, or shape.										Q		
(6) A change in the type of power source, or a change in the arc timing exceeding 1/10 second, or a change in amperage exceeding ±10% from that qualified.												Q
(7) A change in the mode of metal transfer from short circuiting to globular, spray, or pulsed and vice versa.					Q	Q						
2.14.9 Other Variables												
(1) A change in welding process.	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
(2) A change from single electrode to multiple electrodes in the same weld pool, and vice versa.				T	T	Q	Q	Q	Q			
(3) A change from multipass per side to single pass per side.		T	T	T	T	T	T			Q	Q	
(4) A change from the conventional welding to keyhole welding, or vice versa, or, the inclusion of both techniques unless each has been individually qualified.							T					
(5) A change in the stud gun model, or a change exceeding 1/32 in. in the nominal lift.												Q
(6) A change exceeding ±5% in gun-to-workpiece distance, or axis of beam angle related to work.										Q		
(7) A change exceeding ±20% in oscillation length or width from that qualified, or the addition of a cosmetic wash pass.										Q		

	OFW	SMAW	GTAW	SAW	GMAW	FCAW	PAW	ESW	EGW	EBW	LBW	SW
2.14.9 Other Variables (Cont'd)												
(8) A change in design or material of backing shoes.								Q	Q	Q		
(9) A change exceeding ±20% in the oscillation variables for mechanized or automatic welding.			T	T	T	T	T					
(10) A change exceeding ±10% in travel speed for mechanized or automatic welding.			CH	CH	CH	CH	CH					
(11) A change from stringer bead to weave bead for manual welding.		CH	CH	CH	CH	CH	CH					
(12) A change from a stringer to a weave bead, but not vice versa, for M-23, M-24, M-26, and M-27 heat-treatable materials.			Q		Q		Q					
(13) A change from a stringer bead to a weave bead in vertical uphill welding.		T	T		T	T	T					
(14) A change in the nominal size or shape of the stud at the section to be welded.												Q
(15) A change in the type of fuel or type of flame.	Q											
(16) A change from single-sided welds to double-sided or vice versa.										Q	Q	