ARTICLE II
WELDING PROCEDURE QUALIFICATIONS

QW-200 GENERAL

QW-200.1 Each manufacturer and contractor shall prepare written Welding Procedure Specifications which are defined as follows.

(a) Welding Procedure Specification (WPS). A WPS is a written qualified welding procedure prepared to provide direction for making production welds to Code requirements. The WPS or other documents may be used to provide direction to the welder or welding operator to assure compliance with the Code requirements.

(b) Contents of the WPS. The completed WPS shall describe all of the essential, nonessential, and, when required, supplementary essential variables for each welding process used in the WPS. These variables are listed in QW-250 through QW-280 and are defined in Article IV, Welding Data.

The WPS shall reference the supporting Procedure Qualification Record(s) (PQR) described in QW-200.2. The manufacturer or contractor may include any other information in the WPS that may be helpful in making a Code weldment.

(c) Changes to the WPS. Changes may be made in the nonessential variables of a WPS to suit production requirements without requalification provided such changes are documented with respect to the essential, nonessential, and, when required, supplementary essential variables for each process. This may be by amendment to the WPS or by use of a new WPS.

Changes in essential or supplementary essential (when required) variables require requalification of the WPS (new or additional PQRs to support the change in essential or supplementary essential variables).

(d) Format of the WPS. The information required to be in the WPS may be in any format, written or tabular, to fit the needs of each manufacturer or contractor, as long as every essential, nonessential, and, when required, supplementary essential variables outlined in QW-250 through QW-280 is included or referenced.

Form QW-482 (see Nonmandatory Appendix B) has been provided as a guide for the WPS. This Form includes the required data for the SMAW, SAW, GMAW, and GTAW processes. It is only a guide and does not list all required data for other processes. It also lists some variables that do not apply to all processes (e.g., listing shielding gas which is not required for SAW). The guide does not easily lend itself to multiple process procedure specification (e.g., GTAW root with SMAW fill).

(e) Availability of the WPS. A WPS used for Code production welding shall be available for reference and review by the Authorized Inspector (AI) at the fabrication site.

QW-200.2 Each manufacturer or contractor shall be required to prepare a procedure qualification record which is defined as follows.

(a) Procedure Qualification Record (PQR). A PQR is a record of the welding data used to weld a test coupon. The PQR is a record of variables recorded during the welding of the test coupons. It also contains the test results of the tested specimens. Recorded variables normally fall within a small range of the actual variables that will be used in production welding.

(b) Contents of the PQR. The completed PQR shall document all essential and, when required, supplementary essential variables of QW-250 through QW-280 for each welding process used during the welding of the test coupon. Nonessential or other variables used during the welding of the test coupon may be recorded at the manufacturer's or contractor's option. All variables, if recorded, shall be the actual variables (including ranges) used during the welding of the test coupon. If variables are not monitored during welding, they shall not be recorded. It is not intended that the full range or the extreme of a given range of variables to be used in production be used during qualification unless required due to a specific essential or, when required, supplementary essential variable.

The PQR shall be certified accurate by the manufacturer or contractor. The manufacturer or contractor may not subcontract the certification function. This certification is intended to be the manufacturer's or

contractor's verification that the information in the PQR is a true record of the variables that were used during the welding of the test coupon and that the resulting tensile, bend, or macro (as required) test results are in compliance with Section IX.

When more than one welding process or filler metal is used to weld a test coupon, the approximate deposit weld metal thickness of each welding process and filler metal shall be recorded.

(c) Changes to the PQR. Changes to the PQR are not permitted except as described below. It is a record of what happened during a particular welding test. Editorial corrections or addenda to the PQR are permitted. An example of an editorial correction is an incorrect P-Number, F-Number, or A-Number that was assigned to a particular base metal or filler metal. An example of an addendum would be a change resulting from a Code change. For example, Section IX may assign a new F-Number to a filler metal or adopt a new filler metal under an established F-Number. This may permit, depending on the particular construction Code requirements, a manufacturer or contractor to use other filler metals that fall within that particular F-Number where, prior to the Code revision, the manufacturer or contractor was limited to the particular electrode classification that was used during qualification. Additional information can be incorporated into a PQR at a later date provided the information is substantiated as having been part of the original qualification condition by lab record or similar data.

All changes to a PQR require recertification (including date) by the manufacturer or contractor.

(d) Format of the PQR. Form QW-483 (see Nonmandatory Appendix B) has been provided as a guide for the PQR. The information required to be in the PQR may be in any format to fit the needs of each manufacturer or contractor, as long as every essential and, when required, supplementary essential variable, required by QW-250 through QW-280, is included. Also the type of tests, number of tests, and test results shall be listed in the PQR.

Form QW-483 does not easily lend itself to cover combinations of welding processes or more than one F-Number filler metal in one test coupon. Additional sketches or information may be attached or referenced to record the required variables.

(e) Availability of the PQR. PQRs used to support WPSs shall be available, upon request, for review by the Authorized Inspector (AI). The PQR need not be available to the welder or welding operator.

(f) Multiple WPSs With One PQR/Multiple PQRs With One WPS. Several WPSs may be prepared from the data on a single PQR (e.g., a 1G plate PQR may support WPSs for the F, V, H, and O positions on plate or pipe within all other essential variables). A single WPS may cover several essential variable changes as long as a supporting PQR exists for each essential and, when required, supplementary essential variable (e.g., a single WPS may cover a thickness range from $\frac{1}{16}$ in. (1.6 mm) through $1\frac{1}{4}$ in. (32 mm) if PQRs exist for both the $\frac{1}{16}$ in. (1.6 mm) through $\frac{3}{16}$ in. (4.8 mm) and $\frac{3}{16}$ in. (4.8 mm) through $1\frac{1}{4}$ in. (32 mm) thickness ranges).

QW-200.3 To reduce the number of welding procedure qualifications required, P-Numbers are assigned to base metals dependent on characteristics such as composition, weldability, and mechanical properties, where this can logically be done; and for steel and steel alloys (QW/QB-422) Group Numbers are assigned additionally to P-Numbers. These Group Numbers classify the metals within P-Numbers for the purpose of procedure qualification where notch-toughness requirements are specified. The assignments do not imply that base metals may be indiscriminately substituted for a base metal which was used in the qualification test without consideration of the compatibility from the standpoint of metallurgical properties, postweld heat treatment, design, mechanical properties, and service requirements. Where notch toughness is a consideration, it is presupposed that the base metals meet the specific requirements.

In general, notch-toughness requirements are mandatory for all P-No. 11 quenched and tempered metals, for low temperature applications of other metals as applied to Section VIII, and for various classes of construction required by Section III. Acceptance criteria for the notch-toughness tests are as established in the other Sections of the Code.

For certain materials permitted by the ASME/ANSI B31 Code for Pressure Piping or by selected Code Cases of the ASME Boiler and Pressure Vessel Code but which are not included within the ASME Boiler and Pressure Vessel Code Material Specifications (Section II), S-Number groupings are assigned in QW/QB-422. These groupings are similar to the P-Number groupings of QW/QB-422. Qualification limits are given in QW-420.2.

QW-200.4 Combination of Welding Procedures

(a) More than one procedure having different essential or nonessential variables may be used in a single production joint. Each procedure may include one or a combination of processes, filler metals, or other variables.

Where two or more procedures involving different processes or other essential variables are used in one joint, QW-451 shall be used to determine the range of base metal thickness qualified and the maximum thickness of deposited weld metal qualified for each process or procedure. Alternatively, qualification for root deposits only may be made in accordance with QW-200.4(b). The deposited weld metal of each process or procedure shall be included in the tension and bend specimens, and in the notch-toughness specimen (when required). One or more processes or procedures may be deleted from a qualified combination procedure. Each such process or procedure may be used separately provided:

(1) the remaining essential, nonessential, and supplementary essential variables are applied;

(2) the base metal and deposited weld metal thickness limits of QW-451 are applied.

(b) For GTAW, SMAW, GMAW, PAW, and SAW, or combinations of these processes, a PQR for a process recording a test coupon that was at least $\frac{1}{2}$ in. (13 mm) thick may be combined with one or more other PQRs recording another welding process and any greater base metal thickness. In this case, the process recorded on the first PQR may be used to deposit the root layers using the process(es) recorded on that PQR up to 2t (for short-circuiting type of GMAW, see QW-404.32) in thickness on base metal of the maximum thickness qualified by the other PQR(s) used to support the WPS. The requirements of Note (1) of QW-451.1 and QW-451.2 shall apply.

QW-201 Manufacturer's or Contractor's Responsibility

Each manufacturer or contractor shall list the parameters applicable to welding that he performs in construction of weldments built in accordance with this Code. These parameters shall be listed in a document known as a Welding Procedure Specification (WPS).

Each manufacturer or contractor shall qualify the WPS by the welding of test coupons and the testing of specimens (as required in this Code), and the recording of the welding data and test results in a document known as a Procedure Qualification Record (PQR). The welders or welding operators used to produce weldments to be tested for qualification of procedures shall be under the full supervision and control of the manufacturer or contractor during the production of these test weldments. The weldments to be tested for qualification of procedures shall be welded either by direct employees or by individuals engaged by contract for their services as welders or welding operators under the full supervision and control of the manufacturer or contractor. It is not permissible for the manufacturer or contractor to have the supervision and control of welding of the test weldments performed by another organization. It is permissible, however, to subcontract any or all of the work of preparation of test metal for welding and subsequent work on preparation of test specimens from the completed weldment, performance of nondestructive examination, and mechanical tests, provided the manufacturer or contractor accepts the responsibility for any such work.

The Code recognizes a manufacturer or contractor as the organization which has responsible operational control of the production of the weldments to be made in accordance with this Code. If in an organization effective operational control of welding procedure qualification for two or more companies of different names exists, the companies involved shall describe in their Quality Control system/Quality Assurance Program, the operational control of procedure qualifications. In this case separate welding procedure qualifications are not required, provided all other requirements of Section IX are met.

A WPS may require the support of more than one PQR, while alternatively, one PQR may support a number of WPSs.

The manufacturer or contractor shall certify that he has qualified each Welding Procedure Specification, performed the procedure qualification test, and documented it with the necessary Procedure Qualification Record (PQR).

QW-201.1 The Code recognizes that manufacturers or contractors may maintain effective operational control of PQRs and WPSs under different ownership than existed during the original procedure qualification. When a manufacturer or contractor or part of a manufacturer or contractor is acquired by a new owner(s), the PQRs and WPSs may be used by the new owner(s) without requalification, provided all of the following are met:

(a) the new owner(s) takes responsibility for the WPSs and PQRs;

(b) the WPSs reflect the name of the new owner(s);

(c) the Quality Control System/Quality Assurance Program reflects the source of the PQRs as being from the former manufacturer or contractor.

QW-202 Type of Tests Required

QW-202.1 Mechanical Tests. The type and number of test specimens which shall be tested to qualify a groove weld procedure are given in QW-451, and shall

be removed in a manner similar to that shown in QW-463. If any test specimen required by QW-451 fails to meet the applicable acceptance criteria, the test coupon shall be considered as failed, and a new test coupon shall be welded. Where qualification is for fillet welds only, the requirements are given in QW-202.2(c) and (d); and where qualification is for stud welds only, the requirements are given in QW-202.5.

01 **QW-202.2 Groove and Fillet Welds**

(a) Qualification for Groove Full Penetration Welds. Groove-weld test coupons shall qualify the thickness ranges of both base metal and deposited weld metal to be used in production. Limits of qualification shall be in accordance with QW-451. WPS qualification for groove welds shall be made on groove welds using tension and guided-bend specimens. Notch-toughness tests shall be made when required by other Section(s) of the Code. The WPS shall be qualified for use with groove welds within the range of essential variables listed.

(b) Qualification for Partial Penetration Groove Welds. Partial penetration groove welds shall be qualified in accordance with the requirements of QW-451 for both base metal and deposited weld metal thickness, except there need be no upper limit on the base metal thickness provided qualification was made on base metal having a thickness of $1\frac{1}{2}$ in. (38 mm) or more.

(c) Qualification for Fillet Welds. WPS qualification for fillet welds may be made on groove-weld test coupons using test specimens specified in QW-202.2(a) or (b). Fillet-weld procedures so qualified may be used for welding all thicknesses of base metal for all sizes of fillet welds, and all diameters of pipe or tube in accordance with QW-451.4. Nonpressure-retaining fillet welds, as defined in other Sections of the Code, may as an alternate be qualified with fillet welds only. Tests shall be made in accordance with QW-180. Limits of qualification shall be in accordance with QW-451.3.

QW-202.3 Weld Repair and Buildup. WPS qualified on groove welds shall be applicable for weld repairs to groove and fillet welds and for weld buildup under the following provisions.

(a) There is no limitation on the thickness of base metal or deposited weld metal for fillet welds.

(b) For other than fillet welds, the thickness range for base metal and deposited weld metal for each welding process shall be in accordance with QW-451, except there need be no upper limit on the base metal thickness provided qualification was made on base metal having a thickness of $1\frac{1}{2}$ in. (38 mm) or more.

QW-202.4 Dissimilar Base Metal Thicknesses. 01 WPS qualified on groove welds shall be applicable for production welds between dissimilar base metal thicknesses provided:

(a) the thickness of the thinner member shall be within the range permitted by QW-451;

(b) the thickness of the thicker member shall be as follows.

(1) For P-No. 8, P-No. 41, P-No. 42, P-No. 43, P-No. 44, P-No. 45, P-No. 46, P-No. 51, P-No. 52, P-No. 53, P-No. 61, and P-No. 62 metal, there shall be no limitation on the maximum thickness of the thicker production member in joints of similar P-Number materials provided qualification was made on base metal having a thickness of $\frac{1}{4}$ in. (6 mm) or greater.

(2) For all other metal, the thickness of the thicker member shall be within the range permitted by QW-451, except there need be no limitation on the maximum thickness of the thicker production member provided qualification was made on base metal having a thickness of $1\frac{1}{2}$ in. (38 mm) or more.

More than one procedure qualification may be required to qualify for some dissimilar thickness combinations.

QW-202.5 Stud Welding. Procedure qualification tests for stud welds shall be made in accordance with QW-192. The procedure qualification tests shall qualify the welding procedures for use within the range of the essential variables of QW-261. For studs welded to other than P-No. 1 metals, five additional welds shall be made and subjected to a macro-test, except that this is not required for studs used for extended heating surfaces.

QW-203 Limits of Qualified Positions for Procedures

Unless specifically required otherwise by the welding variables (QW-250), a qualification in any position qualifies the procedure for all positions. The welding process and electrodes must be suitable for use in the positions permitted by the WPS. A welder or welding operator making and passing the WPS qualification test is qualified for the position tested. See QW-301.2.

QW-210 PREPARATION OF TEST COUPON

QW-211 Base Metal

The base metals may consist of either plate, pipe, or other product forms. Qualification in plate also qualifies for pipe welding and vice versa. The dimen-

sions of the test coupon shall be sufficient to provide the required test specimens.

QW-212 Type and Dimensions of Groove Welds

Except as otherwise provided in QW-250, the type and dimensions of the welding groove are not essential variables.

QW-213 P-No. 11 Base Metals

For vessels or parts of vessels constructed with P-No. 11 base metals, weld grooves for thickness less than $^{5}/_{8}$ in. (16 mm) shall be prepared by thermal processes, when such processes are to be employed during fabrication. This groove preparation shall also include back gouging, back grooving, or removal of unsound weld metal by thermal processes, when these processes are to be employed during fabrication.

QW-214 Corrosion-Resistant Weld Metal Overlay

QW-214.1 The size of test coupons, limits of qualification, required examinations and tests, and test specimens shall be as specified in QW-453.

QW-214.2 Essential variables shall be as specified in QW-250 for the applicable welding process.

QW-215 Electron Beam Welding and Laser Beam Welding

QW-215.1 The WPS qualification test coupon shall be prepared with the joint geometry duplicating that to be used in production. If the production weld is to include a lap-over (completing the weld by rewelding over the starting area of the weld, as for a girth weld), such lap-over shall be included in the WPS qualification test coupon.

QW-215.2 The mechanical testing requirements of QW-451 shall apply.

QW-215.3 Essential variables shall be as specified in QW-260 and QW-264 for the applicable welding process.

QW-216 Hard-Facing Weld Metal Overlay

Hard-Facing Weld Metal Overlay refers to weld deposits made, using a variety of processes, to deter the effects of wear and/or abrasion. The following requirements apply regardless of which hard-facing process is used.

QW-216.1 The size of test coupons, limits of qualification, required examinations and tests, and test specimens shall be as specified in QW-453.

QW-216.2 Welding variables shall be as specified in QW-250 for the applicable process.

QW-216.3 Where Spray Fuse methods of hard-facing (e.g., Oxyfuel and Plasma Arc) are to be used, the coupons for these methods shall be prepared and welding variables applied in accordance with QW-216.1 and QW-216.2, respectively.

QW-216.4 If a weld deposit is to be used under a hard-facing weld metal overlay, a base metal with an assigned P-Number and a chemical analysis nominally matching the weld deposit chemical analysis may be substituted to qualify the PQR.

QW-217 Joining of Composite (Clad Metals)

The WPS for groove welds in clad metal shall be qualified as provided in QW-217(a) when any part of the cladding thickness, as permitted by the referencing Code Section, is included in the design calculations. Either QW-217(a) or (b) may be used when the cladding thickness is not included in the design calculations.

(a) The essential and nonessential variables of QW-250 shall apply for each welding process used in production. The procedure qualification test coupon shall be made using the same P-Number base metal, cladding, and welding process, and filler metal combination to be used in production welding. For metal not included in QW/QB-422, the metal used in the composite test plate shall be within the range of chemical composition of that to be used in production. The qualified thickness range for the base metal and filler metal(s) shall be based on the actual test coupon thickness for each as applied to QW-451, except that the minimum thickness of filler metal joining the cladding portion of the weldment shall be based on a chemical analysis performed in accordance with QW-453. Tensile and bend tests required in QW-451 for groove welds shall be made, and they shall contain the full thickness of cladding through the reduced section of the specimen. The bond line between the original cladding and the base metal may be disregarded when evaluating side-bend tests if the cladding was applied by a process other than fusion welding.

(b) The essential and nonessential variables of QW-250 shall apply for each welding process used in

production for joining the base metal portion of the weldment. The PQRs that support this portion of the WPS need not be based on test coupons made with clad metal. For the corrosion-resistant overlay portion of the weld, the essential variables of QW-251.4 shall apply and the test coupon and testing shall be in accordance with QW-453. The WPS shall limit the depth of the groove, which will receive the corrosion-resistant overlay in order to ensure development of the full strength of the underlying weld in the base metal.

QW-218 Applied Linings

QW-218.1 WPSs for attaching applied linings shall be qualified in accordance with QW-202.2(a), (b), or (c).

QW-218.2 As an alternative to the above, each process to be used in attaching applied linings to base metal shall be qualified on a test coupon welded into the form and arrangement to be used in construction using materials that are within the range of chemical composition of the metal to be used for the base plate, the lining, and the weld metal. The welding variables of QW-250 shall apply except for those regarding base metal or weld metal thickness. Qualification tests shall be made for each position to be used in production welding in accordance with QW-461.9, except that qualification in the vertical position, uphill progression shall qualify for all positions. One cross section for each position tested shall be sectioned, polished, and etched to clearly show the demarcation between the base metal and the weld metal. In order to be acceptable, each specimen shall exhibit complete fusion of the weld metal with the base metal and freedom from cracks.

QW-218.3 When chemical analysis of the weld deposit for any elements is required, a chemical analysis shall be performed per QW-453, Note 9 for those elements.

QW-250 WELDING VARIABLES

QW-251 General

QW-251.1 Types of Variables for Welding Procedure Specifications (WPS). These variables (listed for each welding process in QW-252 through QW-265) are subdivided into essential variables, supplementary essential variables, and nonessential variables (QW-401). The "Brief of Variables" listed in the Tables are for reference *only*. See the complete variable in Welding Data of Article IV.

QW-251.2 Essential Variables. Essential variables are those in which a change, as described in the specific variables, is considered to affect the mechanical properties of the weldment, and shall require requalification of the WPS.

Supplementary essential variables are required for metals for which other Sections specify notch-toughness tests and are in addition to the essential variables for each welding process.

QW-251.3 Nonessential Variables. Nonessential variables are those in which a change, as described in the specific variables, may be made in the WPS without requalification.

QW-251.4 Special Processes

(a) The special process essential variables for corrosion-resistant and hard-surfacing weld metal overlays are as indicated in the following tables for the specified process. Only the variables specified for special processes shall apply. A change in the corrosion-resistant or hard-surfacing welding process shall require requalification.

(b) WPS qualified for corrosion-resistant and hard-surfacing overlay welding, in accordance with other Sections when such qualification rules were included in those Sections, may be used with the same provisions as provided in QW-100.3.

QW-252
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Oxyfuel Gas Welding (OFW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.2	± Backing			X
	.3	ϕ Backing comp.			X
	.10	ϕ Root spacing			X
QW-403 Base Metals	.1	ϕ P-Number	X		
	.2	Max. *T* qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ AWS class.	X		
QW-405 Positions	.1	+ Position			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)			X
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.7	ϕ Type fuel gas	X		
QW-410 Technique	.1	ϕ String/weave			X
	.2	ϕ Flame characteristics			X
	.4	ϕ $\leftarrow\rightarrow$ Technique			X
	.5	ϕ Method cleaning			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-252.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Oxyfuel Gas Welding (OFW)

Paragraph		Special Process Essential Variables		
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)	Hard-Facing Spray Fuse (QW-216)
QW-402 Joint	.16	< Finished *t*		
	.17			> Finished *t*
QW-403 Base Metals	.20	ϕ P-Number		ϕ P-Number
	.23	ϕ *T* Qualified	ϕ *T* Qualified	ϕ *T* Qualified
QW-404 Filler Metals	.12	ϕ AWS class.		ϕ AWS class.
	.42			> 5% Particle size range
	.46			ϕ Powder feed rate
QW-405 Positions	.4	+ Position		+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass		Dec. > 100°F (56°C) preheat > Interpass
	.5			ϕ Preheat maint.
QW-407 PWHT	.6	ϕ PWHT		ϕ PWHT
	.7			ϕ PWHT after fusing
QW-408 Gas	.7	ϕ Type of fuel gas		
	.14	ϕ Torch type, tip size		
	.16			ϕ > 5% Powder feed rate
	.19			ϕ Plasma/feed gas comp.
QW-410 Technique	.38	ϕ Multi- to single-layer		ϕ Multi- to single-layer
	.39	ϕ Torch type, tip sizer		
	.44			ϕ > 15% Torch to workpiece
	.45			ϕ Surface prep.
	.46			ϕ Spray torch
	.47			ϕ > 10% Fusing temp. or method

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-253
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc (SMAW)

01

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	– Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits impact		X	
	.7	*T*/*t* Limits > 8 in. (203 mm)	X		
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.7	ϕ Diam. > $\frac{1}{4}$ in. (6 mm)		X	
	.12	ϕ AWS class.		X	
	.30	ϕ *t*	X		
	.33	ϕ AWS class.			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (56°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.9	ϕ Multi to single pass/side		X	X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-253.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Shielded Metal-Arc (SMAW)

Paragraph		Special Process Essential Variables	
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)
QW-402 Joints	.16	< Finished *t*	< Finished *t*
QW-403 Base Metals	.20	*φ* P-Number	*φ* P-Number
	.23	*φ* *T* Qualified	*φ* *T* Qualified
QW-404 Filler Metals	.12	*φ* AWS class.	
	.37		*φ* A-Number
	.38	*φ* Dia. (1st layer)	*φ* Dia. (1st layer)
QW-405 Positions	.4	+ Position	+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass
QW-407 PWHT	.6	*φ* PWHT	*φ* PWHT
QW-409 Electrical Characteristics	.4	*φ* Current or polarity	*φ* Current or polarity
	.22	Inc. > 10% 1st layer	Inc. > 10% 1st layer
QW-410 Technique	.38	*φ* Multi- to single-layer	*φ* Multi- to single-layer

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand *φ* Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-254
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Submerged-Arc Welding (SAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	– Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.7	*T*/*t* Limits > 8 in. (203 mm)	X		
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.11	ϕ P-No. qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.9	ϕ Flux/wire class.	X		
	.10	ϕ Alloy flux	X		
	.24	± Supplemental ϕ	X		
	.27	ϕ Alloy elements	X		
	.29	ϕ Flux designation			X
	.30	ϕ *t*	X		
	.33	ϕ AWS class.			X
	.34	ϕ Flux type	X		
	.35	ϕ Flux/wire class.		X	X
	.36	Recrushed slag	X		
QW-405 Positions	.1	+ Position			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (56°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X

QW-254
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Submerged-Arc Welding (SAW) (CONT'D)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-410 Technique	.1	ϕ String/weave			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multi to single pass/side		X	X
	.10	ϕ Single to multi electrodes		X	X
	.15	ϕ Electrode spacing			X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-254.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Submerged-Arc Welding (SAW)

Paragraph		Special Process Essential Variables	
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)
QW-402 Joints	.16	< Finished *t*	< Finished *t*
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number
	.23	ϕ *T* Qualified	ϕ *T* Qualified
QW-404 Filler Metals	.12	ϕ AWS class.	
	.24	± ϕ Supplemental	± ϕ Supplemental
	.27	ϕ Alloy elements	
	.37		ϕ A-Number
	.39	ϕ Nom. flux comp.	ϕ Nom. flux comp.
QW-405 Positions	.4	+ Position	+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass
QW-407 PWHT	.6	ϕ PWHT	ϕ PWHT
QW-409 Electrical Characteristics	.4	ϕ Current or polarity	ϕ Current or polarity
	.26	> Heat input more than 10%	> Heat input more than 10%
QW-410 Technique	.38	ϕ Multi- to single-layer	ϕ Multi- to single-layer
	.40		– Sup. device
	.50	ϕ No. of elec.	ϕ No. of elec.
	.51	± Oscillation	± Oscillation

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-255
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.4	– Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.7	*T*/*t* Limits > 8 in. (203 mm)	X		
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.10	*T* Limits (S. Cir. Arc)	X		
	.11	ϕ P-No. qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ AWS class.		X	
	.23	ϕ Filler metal product form	X		
	.24	± Supplemental ϕ	X		
	.27	ϕ Alloy elements	X		
	.30	ϕ *t*	X		
	.32	*t* Limit (S. Cir. Arc)	X		
	.33	ϕ AWS Class.			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
	.2	ϕ Preheat maint.			X
	.3	Increase > 100°F (56°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		

QW-255
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Metal-Arc Welding (GMAW and FCAW) (CONT'D)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-408 Gas	.1	± Trail or ϕ comp.			X
	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
	.5	± or ϕ Backing flow			X
	.9	– Backing or ϕ comp.	X		
	.10	ϕ Shielding or trailing	X		
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.2	ϕ Transfer mode	X		
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.1	ϕ String/weave			X
	.3	ϕ Orifice, cup, or nozzle size			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multi to single pass/side		X	X
	.10	ϕ Single to multi electrodes		X	X
	.15	ϕ Electrode spacing			X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-255.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Metal-Arc Welding (GMAW and FCAW)

Paragraph		Special Process Essential Variables	
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)
QW-402 Joints	.16	< Finished *t*	< Finished *t*
QW-403 Base Metals	.20	*ϕ* P-Number	*ϕ* P-Number
	.23	*ϕ* *T* Qualified	*ϕ* *T* Qualified
QW-404 Filler Metals	.12	*ϕ* AWS class.	
	.23	*ϕ* Filler metal product form	ϕ Filler metal product form
	.24	± *ϕ* Supplemental	± *ϕ* Supplemental
	.27	*ϕ* Alloy elements	
	.37		*ϕ* A-Number
QW-405 Positions	.4	+ Position	+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass
QW-407 PWHT	.6	*ϕ* PWHT	*ϕ* PWHT
QW-408 Gas	.15	*ϕ* Type or flow rate	*ϕ* Type or flow rate
QW-409 Electrical Characteristics	.4	*ϕ* Current or polarity	*ϕ* Current or polarity
	.26	> Heat input more than 10%	> Heat input more than 10%
QW-410 Technique	.38	*ϕ* Multi- to single-layer	*ϕ* Multi- to single-layer
	.50	*ϕ* No. of elec.	*ϕ* No. of elec.
	.51	± Oscillation	± Oscillation

Legend:
+ Addition – Deletion > Increase/greater than < Decrease/less than ↑ Uphill ↓ Downhill ← Forehand → Backhand *ϕ* Change

QW-256 01
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Tungsten-Arc Welding (GTAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.5	+ Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.7	*T*/*t* Limits > 8 in. (203 mm)	X		
	.8	ϕ *T* Qualified	X		
	.11	ϕ P-No. qualified	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ AWS class.		X	
	.14	± Filler	X		
	.22	± Consum. insert			X
	.23	ϕ Filler metal product form	X		
	.30	ϕ *t*	X		
	.33	ϕ AWS class.			X
	.50	± Flux			X
QW-405 Positions	.1	+ Position			X
	.2	ϕ Position		X	
	.3	ϕ ↑↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
	.3	Increase > 100°F (56°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T &T range)		X	
	.4	*T* Limits	X		
QW-408 Gas	.1	± Trail or ϕ comp.			X
	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
	.5	± or ϕ Backing flow			X
	.9	– Backing or ϕ comp.	X		
	.10	ϕ Shielding or trailing	X		

QW-256
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Tungsten-Arc Welding (GTAW) (CONT'D)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.3	± Pulsing I			X
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
	.12	ϕ Tungsten electrode			X
QW-410 Technique	.1	ϕ String/weave			X
	.3	ϕ Orifice, cup, or nozzle size			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.9	ϕ Multi to single pass/side		X	X
	.10	ϕ Single to multi electrodes		X	X
	.11	ϕ Closed to out chamber	X		
	.15	ϕ Electrode spacing			X
	.25	ϕ Manual or automatic			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-256.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Gas Tungsten-Arc Welding (GTAW)

Paragraph		Special Process Essential Variables	
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)
QW-402 Joints	.16	< Finished *t*	< Finished *t*
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number
	.23	ϕ *T* Qualified	ϕ *T* Qualified
QW-404 Filler Metals	.12	ϕ AWS Class.	
	.14	± Filler	± Filler
	.23	ϕ Filler metal product form	ϕ Filler metal product form
	.37		ϕ A-Number
QW-405 Positions	.4	+ Position	+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass
QW-407 PWHT	.6	ϕ PWHT	ϕ PWHT
QW-408 Gas	.15	ϕ Type or flow rate	ϕ Type or flow rate
QW-409 Electrical Characteristics	.4	ϕ Current or polarity	ϕ Current or polarity
	.26	> Heat input more than 10%	> Heat input more than 10%
QW-410 Technique	.38	ϕ Multi- to single-layer	ϕ Multi- to single-layer
	.50	ϕ No. of elec.	ϕ No. of elec.
	.51	± Oscillation	± Oscillation

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

A02

QW-257
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Plasma-Arc Welding (PAW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design		X	
	.5	+ Backing			X
	.10	ϕ Root spacing			X
	.11	± Retainers			X
QW-403 Base Metals	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.8	ϕ *T* Qualified	X		
	.12	ϕ P-Number/melt-in	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.3	ϕ Size			X
	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.12	ϕ AWS class.		X	
	.14	± Filler	X		
	.22	± Consum. insert			X
	.23	ϕ Filler metal product form	X		
	.27	ϕ Alloy elements	X		
	.30	ϕ *t*	X		
	.33	ϕ AWS class.			X
QW-405 Positions	.1	+ Position			X
	ϕ	.2 Position		X	
	.3	ϕ ↑ ↓ Vertical welding			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
	.3	Increase > 100°F (56°C) (IP)		X	
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-408 Gas	.1	± Trail or ϕ comp.			X
	.4	ϕ Composition	X		
	.5	± Or ϕ backing flow			X
	.9	– Backing or ϕ comp.	X		
	.10	ϕ Shielding or trailing	X		
	.21	ϕ Flow rate			X

QW-257
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Plasma-Arc Welding (PAW) (CONT'D)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
	.12	ϕ Tungsten electrode			X
QW-410 Technique	.1	ϕ String/weave			X
	.3	ϕ Orifice, cup, or nozzle size			X
	.5	ϕ Method cleaning			X
	.6	ϕ Method back gouge			X
	.7	ϕ Oscillation			X
	.9	ϕ Multi to single pass/side		X	X
	.10	ϕ Single to multi electrodes		X	X
	.11	ϕ Closed to out chamber	X		
	.12	ϕ Melt-in to keyhole		X	
	.15	ϕ Electrode spacing			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-257.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Plasma-Arc Welding (PAW)

Paragraph		Special Process Essential Variables		
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)	Hard-Facing Spray Fuse (QW-216)
QW-402 Joints	.16	< Finished *t*	< Finished *t*	
	.17			< Finished *t*
QW-403 Base Metals	.20	ϕ P-Number	ϕ P-Number	ϕ P-Number
	.23	ϕ *T* Qualified	ϕ *T* Qualified	
QW-404 Filler Metals	.12	ϕ AWS class.		ϕ AWS class.
	.14	± Filler	± Filler	
	.37		ϕ A-Number	
	.41	ϕ > 10% powder feed rate	ϕ > 10% powder feed rate	
	.42			ϕ < 5% Particle size range
	.43	ϕ Particle size	ϕ Particle size	
	.44	ϕ Powder type	ϕ Powder type	
	.45	ϕ Filler met. form	ϕ Filler met. form	
	.46			ϕ Powder feet rate
QW-405 Positions	.4	+ Position	+ Position	+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass
	.5			ϕ Preheat maintenance
QW-407 RWHT	.6	ϕ PWHT	ϕ PWHT	ϕ PWHT
	.7			ϕ PWHT after fusing
QW-408 Gas	.16	ϕ > 5% Arc or metal feed gas	ϕ > 5% Arc or metal feed gas	ϕ > 5% Arc or metal feed gas
	.17	ϕ Type or mixture	ϕ Type or mixture	
	.18	ϕ > 10% Mix. comp.	ϕ > 10% Mix. comp.	
	.19			ϕ Plasma/feed gas comp.
	.20			ϕ Plasma gas flow-rate range
QW-409 Electrical Characteristics	.4	ϕ Current or polarity	ϕ Current or polarity	
	.12			ϕ Type or size electrode
	.23			ϕ > 10% I & E
	.24	ϕ > 10% Filler wire watt.	ϕ > 10% Filler wire watt.	
	.25	ϕ > 10% I & E	ϕ > 10% I & E	

QW-257.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Plasma-Arc Welding (PAW) (CONT'D)

Paragraph		Special Process Essential Variables		
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)	Hard-Facing Spray Fuse (QW-216)
QW-410 Technique	.38	ϕ Multi- to single-layer	ϕ Multi- to single-layer	ϕ Multi- to single-layer
	.41	ϕ > 15% Travel speed	ϕ > 15% Travel speed	
	.42	± Oscillation	± Oscillation	
	.43			ϕ > 10% Travel speed range
	.44			ϕ > 15% Torch to workplace
	.45			ϕ Surface prep.
	.46			ϕ Spray torch
	.47			ϕ > 10% Fusing temp. or method
	.48	ϕ Transfer mode	ϕ Transfer mode	ϕ Transfer mode
	.49	ϕ Torch orifice dia.	ϕ Torch orifice dia.	
	.52	ϕ Filler metal del.	ϕ Filler metal del.	

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-258
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electroslag Welding (ESW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.10	ϕ Root spacing			X
	.11	± Retainers	X		
QW-403 Base Metals	.1	ϕ P-Number	X		
	.4	ϕ Group Number		X	
	.9	*t* Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ AWS class.		X	
	.17	ϕ Flux type or comp.	X		
	.18	ϕ Wire to plate	X		
	.19	ϕ Consum. guide	X		
	.33	ϕ AWS class.			X
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-409 Electrical Characteristics	.5	ϕ ±15% I & E range	X		
QW-410 Technique	.5	ϕ Method cleaning			X
	.7	ϕ Oscillation	X		
	.10	ϕ Single to multi electrodes	X		
	.15	ϕ Electrode spacing			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-258.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electroslag Welding (ESW)

Paragraph		Special Process Essential Variables	
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)
QW-402 Joints	.16		< Finished *t*
QW-403 Base Metals	.20		ϕ P-Number
	.23		ϕ *T* Qualified
QW-404 Filler Metals	.24		± Supplemental ϕ
	.37		ϕ A-Number
	.39		ϕ Nom. flux comp.
QW-406 Preheat	.4		Dec. > 100°F preheat > Interpass
QW-407 PWHT	.6		ϕ PWHT
QW-409 Electrical Characteristics	.4		ϕ Current or polarity
	.26		> Heat input more than 10%
QW-410 Technique	.38		ϕ Multi- to single-layer
	.40		– Sup. device
	.50		ϕ No. of elec.
	.51		± Oscillation

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-259
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electrogas Welding (EGW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design			X
	.10	ϕ Root spacing			X
	.11	± Retainers	X		
QW-403 Base Metal	.1	ϕ P-Number	X		
	.5	ϕ Group Number		X	
	.6	*T* Limits		X	
	.8	ϕ *T* Qualified	X		
	.9	*t* Pass > $\frac{1}{2}$ in. (13 mm)	X		
	.13	ϕ P-No. 5/9/10	X		
QW-404 Filler Metals	.4	ϕ F-Number	X		
	.5	ϕ A-Number	X		
	.6	ϕ Diameter			X
	.12	ϕ AWS class.		X	
	.23	ϕ Filler metal product form	X		
	.33	ϕ AWS class.			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)			X
QW-407 PWHT	.1	ϕ PWHT	X		
	.2	ϕ PWHT (T & T range)		X	
	.4	*T* Limits	X		
QW-408 Gas	.2	ϕ Single, mixture, or %	X		
	.3	ϕ Flow rate			X
QW-409 Electrical Characteristics	.1	> Heat input		X	
	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
QW-410 Technique	.5	ϕ Method cleaning			X
	.7	ϕ Oscillation			X
	.8	ϕ Tube-work distance			X
	.9	ϕ Multi to single pass/side		X	X
	.10	ϕ Single to multi electrodes	X		
	.15	ϕ Electrode spacing			X
	.26	± Peening			X

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

GENERAL NOTE: Automated vertical gas metal-arc welding for vertical position only.

QW-260
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Electron Beam Welding (EBW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design	X		
	.2	± Backing	X		
	.6	> Fit-up gap	X		
QW-403 Base Metals	.1	ϕ P-Number	X		
	.3	ϕ Penetration	X		
	.13	ϕ P-No. 5/9/10	X		
	.15	ϕ P-Number	X		
QW-404 Filler Metals	.1	ϕ Cross section or speed	X		
	.2	< t or ϕ comp.	X		
	.8	± or ϕ Chem. comp.	X		
	.14	± Filler	X		
	.20	ϕ Method of addition	X		
	.21	ϕ Analysis	X		
	.33	ϕ AWS class.			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.6	ϕ Environment	X		
QW-409 Electrical Characteristics	.6	ϕ I, E, speed, distance, osc.	X		
	.7	ϕ Pulsing frequency	X		
QW-410 Technique	.5	ϕ Method cleaning			X
	.7	ϕ Oscillation	X		
	.14	ϕ Angle of beam axis	X		
	.17	ϕ Type equip.	X		
	.18	> Pressure of vacuum	X		
	.19	ϕ Filament type, size, etc.	X		
	.20	+ Wash pass	X		
	.21	1 vs. 2 side welding	X		

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-261
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Stud Welding

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.8	ϕ Stud shape size	X		
	.9	ϕ Flux or ferrule	X		
QW-403 Base Metal	.17	ϕ Base metal or stud metal P-No.	X		
QW-405 Positions	.1	+ Position	X		
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.2	ϕ Single, mixture, or %	X		
QW-409 Electrical Characteristics	.4	ϕ Current or polarity		X	X
	.8	ϕ I & E range			X
	.9	ϕ Arc timing	X		
	.10	ϕ Amperage	X		
	.11	ϕ Power source	X		
QW-410 Technique	.22	ϕ Gun model or lift	X		

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-262
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Inertia and Continuous Drive Friction Welding

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joint	.12	ϕ ± 10 deg.	X		
		ϕ Cross section > 10%	X		
		ϕ O. D. > ±10%	X		
		ϕ Solid-to-tube	X		
QW-403 Base Metal	.19	ϕ Base metal	X		
QW-406 Preheat	.1	ϕ Decrease > 100°F (56°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.6	ϕ Environment	X		
QW-410 Technique	.27	ϕ Spp. > ±10%	X		
	.28	ϕ Load > ±10%	X		
	.29	ϕ Energy > ±10%	X		
	.30	ϕ Upset > ±10%	X		

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-263
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
RESISTANCE WELDING

Paragraph		Brief of Variables	Essential	Nonessential
QW-402 Joints	.13	ϕ Spot, projection, seam	X	
	.14	ϕ Overlap, spacing	X	
	.15	ϕ Projection shape, size	X	
QW-403 Base Metals	.1	ϕ P-No.	X	
	.21	$\pm$ Coating, plating	X	
	.22	$\pm$ *T*	X	
QW-406 Preheat	.6	ϕ Amplitude, cycles	X	
QW-407 PWHT	.5	ϕ PWHT	X	
QW-409 Electrical	.13	ϕ RWMA class	X	
	.14	$\pm$ ϕ Slope	X	
	.15	ϕ Pressure, current, time	X	
	.16	Timing	X	
	.17	ϕ Power supply		X
	.18	Tip cleaning		X
QW-410 Technique	.31	ϕ Cleaning method	X	
	.32	ϕ Pressure, time	X	
	.33	ϕ Equipment	X	
	.34	ϕ Cooling medium		X
	.35	ϕ Throat		X

Legend:
+ Addition > Increase/greater than $\uparrow$ Uphill $\leftarrow$ Forehand ϕ Change
– Deletion < Decrease/less than $\downarrow$ Downhill $\rightarrow$ Backhand

QW-264
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Laser Beam Welding (LBW)

Paragraph		Brief of Variables	Essential	Supplementary Essential	Nonessential
QW-402 Joints	.1	ϕ Groove design	X		
	.2	± Backing	X		
	.6	> Fit-up gap	X		
	.18	ϕ Lap joint config.	X		
QW-403 Base Metals	.1	ϕ P-Number	X		
	.3	ϕ Penetration	X		
	.13	ϕ P-No. 5/9/10	X		
	.15	ϕ P-Number	X		
QW-404 Filler Metals	.1	ϕ Cross section or speed	X		
	.2	< t or ϕ comp.	X		
	.8	± or ϕ Chem. comp.	X		
	.14	± Filler	X		
	.20	ϕ Method of addition	X		
	.21	ϕ Analysis	X		
	.33	ϕ AWS class.			X
QW-406 Preheat	.1	Decrease > 100°F (56°C)	X		
QW-407 PWHT	.1	ϕ PWHT	X		
QW-408 Gas	.2	ϕ Single, mixture, or %	X		
	.6	ϕ Environment	X		
	.11	± Gases	X		
	.12	ϕ > 5% Gases	X		
	.13	ϕ Plasma jet position	X		
QW-409 Electrical Characteristics	.19	ϕ Pulse	X		
	.20	ϕ Mode, energy	X		
	.21	ϕ Power, speed, d/fl, distance	X		
QW-410 Technique	.5	ϕ Method cleaning			X
	.7	ϕ Oscillation	X		
	.14	ϕ Angle of beam axis	X		
	.17	ϕ Type equip.	X		
	.20	+ Wash pass	X		
	.21	1 vs. 2 side welding	X		
	.37	ϕ Single to mult. pass	X		

Legend:
+ Addition > Increase/greater than ↑ Uphill ← Forehand ϕ Change
– Deletion < Decrease/less than ↓ Downhill → Backhand

QW-264.1
WELDING VARIABLES PROCEDURE SPECIFICATIONS (WPS)
Laser Beam Welding (LBW)

Paragraph		Special Process Essential Variables	
		Hard-Facing Overlay (QW-216)	Corrosion-Resistant Overlay (QW-214)
QW-402 Joints	.16	< finished *t*	< finished *t*
QW-403 Base Metals	.13	ϕ P-Number 5/9/10	ϕ P-Number 5/9/10
	.20	ϕ P-Number	ϕ P-Number
QW-404 Filler Metals	.12	ϕ AWS class.	ϕ AWS class.
	.27	ϕ Alloy elements	ϕ Alloy elements
	.44	ϕ Particle type	ϕ Particle type
	.47	ϕ Filler/powder metal size	ϕ Filler/powder metal size
	.48	ϕ Powder metal density	ϕ Powder metal density
	.49	ϕ Filler/powder metal feed rate	ϕ Filler/powder metal feed rate
QW-405 Positions	.1	+ Position	+ Position
QW-406 Preheat	.4	Dec. > 100°F (56°C) preheat > Interpass	Dec. > 100°F (56°C) preheat > Interpass
QW-407 PWHT	.6	ϕ PWHT	ϕ PWHT
QW-408 Gas	.2	ϕ Single, mixture, or %	ϕ Single, mixture, or %
	.6	ϕ Environment	ϕ Environment
	.11	± Gases	± Gases
	.12	ϕ % flow rate	ϕ % flow rate
	.13	ϕ Plasma jet position	ϕ Plasma jet position
QW-409 Electrical Characteristics	.19	ϕ Pulse	ϕ Pulse
	.20	ϕ Mode, energy	ϕ Mode, energy
	.21	ϕ Power, speed, d/fl, distance	ϕ Power speed, d/fl, distance
QW-410 Technique	.7	ϕ Oscillation	ϕ Oscillation
	.14	ϕ Angle of beam axis	ϕ Angle of beam axis
	.17	ϕ Type equip.	ϕ Type equip.
	.38	ϕ Multi- to single-layer	ϕ Multi- to single-layer
	.45	ϕ Method of surface prep.	ϕ Method of surface prep.
	.52	ϕ Filler metal delivery	ϕ Filler metal delivery
	.53	ϕ Overlap, spacing	ϕ Overlap, spacing

Legend:
+ Addition > Increase/greater than ϕ Change
– Deletion < Decrease/less than

QW-283 Welds With Buttering

QW-283.1 Scope. This paragraph only applies when the essential variables for the buttering process are different than the essential variables for the process used for subsequent completion of the joint. Common examples are:

(a) the buttered member is heat treated and the completed weld is not heat treated after welding; and

(b) the filler metal used for buttering has a different F-number from that used for the subsequent completion of the weld.

QW-283.2 Tests Required. The procedure shall be qualified by buttering the test coupon (including heat treating of the buttered member when this will be done in production welding) and then making the subsequent weld joining the members. The variables for the buttering and for the subsequent weld shall be in accordance with QW-250, except that QW-409.1 shall be an essential variable for the welding process(es) used to complete the weld when the minimum buttering thickness is less than $^{3}/_{16}$ in. (4.8 mm). Mechanical testing of the completed weldment shall be in accordance with QW-202.2(a).

If the buttering is done with filler metal of the same composition as the filler metal used to complete the weld, one weld test coupon may be used to qualify the dissimilar metal joint by welding the first member directly to the second member in accordance with Section IX.

QW-283.3 Buttering Thickness. The thickness of buttering which shall remain on the production buttered member after all machining and grinding is completed and before subsequent completion of the joint shall be required by the WPS. When this thickness is less than $^{3}/_{16}$ in. (4.8 mm), the thickness of buttering on the test coupon shall be measured before the buttered member is welded to the second member. This thickness shall become the minimum qualified thickness of buttering.

01 **QW-283.4 Qualification Alternative.** When an essential variable is changed in the portion of the weld to be made after buttering or when a different organization is performing the portion of the weld to be made after buttering, a new qualification shall be performed in accordance with one of the following methods:

(a) Qualify in accordance with QW-283.2 and QW-283.3. When the original qualification buttering thickness is less than $^{3}/_{16}$ in. (4.8 mm), the buttering thickness shall not be greater, nor the heat input higher than was used on the original qualification.

(b) When the original qualification buttering thickness is $^{3}/_{16}$ in. (4.8 mm) or greater, qualify the portion of the weld to be made after buttering using any P-Number material that nominally matches the chemical analysis of the buttering weld metal for the buttered base metal of the test coupon.

QW-284 Resistance Welding Machine Qualification

Each resistance welding machine shall be tested to determine its ability to make welds consistently and reproducibly. A machine shall be requalified whenever it is rebuilt, moved to a new location requiring a change in power supply, when the power supply is changed, or any other significant change is made to the equipment. Spot and projection welding machine qualification testing shall consist of making a set of 100 consecutive welds. Every fifth of these welds shall be subjected to mechanical shear tests. Five welds, which shall include one of the first five and one of the last five of the set shall be metallographically examined. Seam welding machine qualification testing shall be the same as procedure qualification testing required per QW-286. Maintenance or adjustment of the welding machine shall not be permitted during welding of a set of test welds. Qualification testing on any P-No. 21 through P-No. 25 aluminum alloy shall qualify the machine for all materials. Qualification on P-No. 1 through P-No. 11 iron-base alloys and any P-No. 41 through P-No. 47 nickel-base alloys shall qualify the machine for all P-No. 1 through P-No. 11 and P-No. 41 through P-No. 47 metals. Testing and acceptance criteria shall be in accordance with QW-196.

QW-285 Resistance Spot and Projection Weld Procedure Qualification

Procedure qualification testing for spot or projection welds shall be done following a Welding Procedure Specification, and it shall consist of making a set of 10 consecutive welds. Five of these welds shall be subjected to mechanical shear tests and five to metallographic examination. Examination, testing, and acceptance criteria shall be in accordance with QW-196.

QW-286 Resistance Seam Weld Procedure Qualification

Plates shall be prepared by welding or brazing a pipe nipple to one of the plates at a hole in one of the plates, and then the plates shall be welded around the edges, sealing the space between the plates as

shown in QW-462.7. The space between the plates shall be pressurized until failure occurs. The procedure qualification is acceptable if failure occurs in the base metal. An additional seam weld at least 6 in. (152 mm) long shall be made between plates of the same thickness as to be used in production welding, and this plate shall be cut into six approximately equal width strips and one cross section of each strip shall be metallographically examined and meet the requirements of QW-196.