

shall be pressurized hydrostatically until failure occurs. The procedure qualification is acceptable if failure occurs in the base metal.

QW-286.3 A test coupon at least 10 in. (250 mm) long shall be made per Figure QW-462.7.2. This test coupon shall be cut transverse to the length of the weld into ten pieces, each approximately 1 in. (25 mm) long. Four transverse weld specimens and four longitudinal weld cross section specimens shall be cut and prepared as detailed in Figure QW-462.7.2. The specimens shall be metallographically examined for compliance with the requirements of QW-196.

QW-287 VARIATION OF SETTINGS FOR ELECTRIC RESISTANCE WELDING

Settings for preheating cycles, electrode pressure, welding current, welding time cycle, or postheating cycles may be varied by $\pm 5\%$ from the values recorded on the PQR, or by $\pm 10\%$ when only one of the above settings is changed.

(19) QW-288 TUBE-TO-TUBESHEET QUALIFICATION ESSENTIAL VARIABLES

Essential variables applicable to tube-to-tubesheet welding procedure qualifications in accordance with QW-193 are listed in Table QW-288.1 for all welding processes except explosion welding and Table QW-288.2 for explosion welding. Essential procedure qualification variables applicable for each welding process listed in QW-250 shall also be observed in addition to the variables of QW-288. A change in the welding process used shall require requalification.

Table QW-288.1
Essential Variables for Procedure Qualification of Tube-to-Tubesheet Welding (All Welding Processes Except Explosion Welding)

Paragraph	Brief of Variables	
QW-402 Joints	.31	< Ligament size
	.32	ϕ Joint configuration
QW-403 Base Metals	.18	ϕ P-Number or A-Number
	.32	ϕ Tube thickness
	.33	< Cladding thickness
	.34	ϕ P-Number
QW-404 Filler Metals	.3	ϕ Filler metal size
	.58	\pm Preplaced filler metal
	.59	ϕ A-number
QW-405 Positions	.3	ϕ \updownarrow Vertical welding
	.4	ϕ Position
QW-406 Preheat	.1	Decrease $>100^\circ\text{F}$ (55°C)
	.3	Increase $>100^\circ\text{F}$ (55°C) (IP)

Table QW-288.1
Essential Variables for Procedure Qualification of Tube-to-Tubesheet Welding (All Welding Processes Except Explosion Welding) (Cont'd)

Paragraph	Brief of Variables	
QW-407 PWHT	.1	ϕ PWHT
QW-409 Electrical Characteristics	.4	ϕ Polarity
	.10	ϕ Amperage
QW-410 Technique	.5	ϕ Method of cleaning
	.37	Single to multiple pass
	.81	+ Tube expansion

Legend:

+ Addition

- Deletion

ϕ Amperage

< Decrease or less than

ϕ Change

GENERAL NOTE: QW-403.32, QW-404.59, QW-405.3, QW-406.1, QW-406.3, QW-409.4, QW-409.10, QW-410.25, and QW-410.37 do not apply to explosion welding.

Table QW-288.2
Essential Variables for Procedure Qualification of Tube-to-Tubesheet Welding (Explosion Welding)

Paragraph	Brief of Variables	
QW-403 Base Metals	.35	ϕ Tube thickness
QW-410 Technique	.82	ϕ Pressure application
	.83	ϕ Explosive
	.84	ϕ Distance charge to tubesheet
	.85	ϕ Specified clearance

Legend:

ϕ Change

QW-289 LOW-ENERGY CAPACITOR DISCHARGE WELDING (19)

The following requirements apply to low-energy capacitor discharge welding:

(a) The energy output shall be limited to 125 W-sec.

(b) A Welding Procedure Specification describing the capacitor discharge equipment, the combination of materials to be joined, and the technique of application shall be prepared; qualification of the welding procedure is not required.

(c) If specific qualification test requirements are not specified by the applicable Code Section, welders and welding operators shall be qualified with one of the following methods:

(1) a demonstration mockup per the requirements of QW-193.2, except that for welding operators

(-a) the hole pattern does not need to be duplicated

(-b) the type or model of equipment is an essential variable

(2) a groove-weld qualification per the requirements of QW-303.1

QW-389 CAPACITOR DISCHARGE WELDING OPERATOR QUALIFICATION

(19)

Welding operators using low-energy capacitor discharge welding in accordance with QW-289 are not required to be qualified.

(19)

Table QW-388
Essential Variables for Tube-to-Tubesheet
Performance Qualification
(Welders; All Welding Processes)

Paragraph		Brief of Variables
QW-402 Joints	.31	≤ Ligament size
	.32	φ Joint configuration
QW-403 Base Metals	.16	φ Tube diameter
	.32	φ Tube thickness
QW-404 Filler Metals	.58	± Preplaced filler metal
QW-409 Electrical	.10	→ Amperage

Legend:
 φ Change
 ± Addition or deletion
 → Increase

≤ Less than or equal to

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QW-403.19 A change to another base material type or grade (type or grade are materials of the same nominal chemical analysis and mechanical property range, even though of different product form), or to any other base material type or grade. When joints are made between two different types or grades of base material, a procedure qualification must be made for the applicable combinations of materials, even though procedure qualification tests have been made for each of the two base materials welded to itself.

- (19) **QW-403.20** If the chemical composition of the weld metal overlay is specified in the WPS, a change in the P-Number listed in Table QW/QB-422 to another P-Number or unlisted base metal, or a change in Group Number for P-No. 10 or P-No. 11 base metals.

If the chemical composition of the weld metal overlay is not specified in the WPS, qualification on P-No. 5A or any lower P-Number base metal also qualifies for weld metal overlay on all lower P-Number base metals.

QW-403.21 The addition or deletion of a coating, plating or cladding, or a change in the nominal chemical analysis or thickness range of the coating or cladding, or a change in type of coating or cladding.

QW-403.22 A change in the thickness of the weld metal overlay exceeding 10% of the thickness of the base metal.

QW-403.23 A change in base metal thickness greater than 20% of the test coupon thickness for fixed-pin and retracting-pin rotating tools.

QW-403.24 A change in the specification, type, or grade of the base metal. When joints are to be made between two different base metals, a procedure qualification must be made for the applicable combination even though procedure qualifications have been made for each of the two base metals welded to themselves.

QW-403.25 Welding procedure qualifications shall be made using a base metal of the same P-Number and Group Number as the base metal to be temper bead welded. When joints are to be made between base metals from two different P-Number and Group Number combinations, a temper bead procedure qualification must be made for each base metal P-Number and Group Number combination to be used in production; this may be done in separate test coupons or in combination on a single test coupon. When base metals of different P-Number and Group Number combinations are tested in the same coupon, the welding variables utilized and test results on each member of the coupon shall be documented independently but may be reported on the same qualification record. Where temper bead welding is to be applied to only one member of a joint (e.g., on the P-No. 1 member of a joint between P-No. 1 and P-No. 8 metals) or where cladding is being applied or repaired using temper bead techniques, qualification in accordance with QW-290 is required only for the portion of the WPS that applies to welding on the member to be temper bead welded.

QW-403.26 An increase in the base metal carbon equivalent using the following equation:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

QW-403.27 The maximum thickness qualified is the thickness of the test coupon, T , or it is unlimited if the test coupon is $1\frac{1}{2}$ in. (38 mm) thick or thicker. However, where T is $\frac{1}{4}$ in. (6 mm) or less, the maximum thickness qualified is $2T$. This limitation applies to fillet welds as well as to groove welds.

QW-403.28 A change to another base metal type, grade, or UNS number.

QW-403.29 A change in the surface finish as defined by the material specification or established surface roughness range as measured in accordance with ASME B46.1-2006.

QW-403.30 A change in base metal thickness greater than 20% of the test coupon thickness for fixed-pin and retracting-pin rotating tools.

(a) of the test coupon thickness for fixed-pin and retracting-pin rotating tools

(b) beyond the minimum and maximum thickness or thickness of the test coupon for self-reacting rotating tools

~~QW-403.31~~ 0.100 in. (2.5 mm) or less, or to increase it to $\frac{1}{2}T$. For tubes 0.100 in. (2.5 mm) or less, or to increase it to $\frac{1}{2}T$.

~~QW-403.32~~ tube or tubesheet material is part of the A-Number or in the nominal composition of the tubesheet cladding or of the A-Number is not part of the A-Number.

~~QW-403.33~~ thickness or diameter of the test coupon or wall thickness

**QW-403.31
DELETED**

QW-403.32

1/2 wall thickness of tube wall thickness increase it to less than thickness greater than ion test is required.

QW-403.33

number of either the cladding or overlay in the P-Number or in the nominal composition of the tubesheet cladding or of the A-Number or in a P-Number or

QW-403.34

fixed tube wall thickness or all diameters and

QW-404 FILLER METALS

QW-404.1 An increase of greater than 10% in the cross-sectional area of the filler metal added (excluding buttering) or in the wire-feed speed beyond that qualified.

QW-404.2 A decrease in the thickness or change in nominal specified chemical analysis of weld metal buttering beyond that qualified. (Buttering or surfacing is the deposition of weld metal on one or both faces of the joint prior to preparation of the joint for final electron beam welding.)

QW-404.3 A change in the size of the filler metal.