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  QW-41 Filler Metals	.18	φ	P-Number or A-Number	
	.32	φ	Tube thickness 📿	
	.33	<	Cladding thickness	
	-34-	φ	P-Number	
	.3	φ	Filler metal size	
	.58	±	Preplaced filler metal	
	.59	φ	A-number	
QW-405 Positions	.3	φ	↑↓ Vertical welding	
	.4	φ	Position	
QW-406 Preheat	.1		Decrease >100°F (55°C)	
	.3		Increase >100°F (55°C) (IP)	

#### Table OW-288.1 **Essential Variables for Procedure** Qualification of Tube-to-Tubesheet Welding (All Welding Processes Except Explosion Welding) (Cont'd) Brief of Variables Paragraph QW-407 .1 **PWHT PWHT** OW-409 .4 Polarity φ Electrical .10 Amperage Characteristics

ф

Method of cleaning

Tube expansion

Single to multiple pass

Legend:	
+ Addition - Deletion	< Decrease or less than
->- Amperage	$\phi$ Change

.5

.37

.81

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-\* -Tubesheet Welding (Exploring)

Paragraph		30	rief 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:  $\phi$  Change

QW-410

Technique

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

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  $\,$

(19)

#### Table QW-388 Essential Variables for Tube-to-Tubesheet **Performance Qualification** (Welders; All Welding Processes) **Brief of Variables** Paragraph .31 QW-402 Ligament size Joints .32 $\phi$ Joint configuration .16 Tube diameter QW-403 Base Metals Tube thickness .32 QW-404 ± Preplaced filler metal .58 Filler Metals QW-409 .10 Amperage Electrical Legend: $\phi$ Change Increase ± Addition or deletion ≤Less than or equal to

## 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.

QW-402.14 An increase or decrease of more than 10% in the spacing of the welds when they are within two diameters of each other.

QW-402.15 A change in the size or shape of the projection in projection welding.

QW-402.16 A decrease in the distance between the approximate weld interface and the final surface of the production corrosion-resistant or hard-facing weld metal overlay below the minimum thickness qualified as shown in Figures QW-462.5(a) through QW-462.5(e). There is no limit on the maximum thickness for corrosionresistant or hard-facing weld metal overlay that may be used in production.

QW-402.30

DELETED

QW-402.17 An increase in duction spray fuse hard-facing ness deposited on the proce coupon.

QW-402.18 For lap joints,

(a) a decrease of more than 1 edge of the material

-QW-402.20

(19)

- (b) an increase in the number of layers of material
- (c) a change in surface preparation or finish from that qualified

QW-402.19 A change in the nominal diameter or nominal thickness for tubular cross sections, or an increase in the total cross section area beyond that qualified for all nontubular cross sections.

-DELETED

QW-402.27 A change in material of fixed backing anvils (when used). A change in backing anvil design that affects the weld cooling rate (e.g., a change from air-cooled to water-cooled, and vice versa). This variable is not applicable to tube-to-tubesheet or double-sided welds with overlapping fusion zones, or welds completed using selfreacting pins.

QW-402.28 A change in joint design from that qualified, including edge preparation geometry (e.g., a change from square butt edge to beveled edge), reductions in the smallest joint path radius to less than the shoulder radius, or joint paths crossing themselves or another HAZ.

QW-402.29 A change in joint spacing greater than ±10% of the qualification test coupon thickness. For WPSs qualified using , the maximum al-

lowable joint sp m). QW-402.30 QW.402.31 more in the specified width of th be holes when the specified width is than the greater of  $\frac{3}{8}$  in. (10 m) specified tube wall thickness.

QW-402.32 QW-402.31 et welding: an in- (19) crease in the de an increase or decrease in the p ie weld groove by more than 5 des groove type.

#### QW-403 **BASE METALS**

**QW-402.20** A change in the joint configuration.

A change from a base metal listed under

:ted unl. When e differe made s, even

each of

QW-402.21 A change in the meth used to minimize internal flash.

**QW-402.22** A change in the end preparation method.

**QW-402.23** For test coupons less than  $1^{1}/_{2}$  in. (38 mm) thick, the addition of a cooling medium (water, flowing gas, etc.) to the back side of the weld. Qualification on test coupons less than  $1\frac{1}{2}$  in. (38 mm) thick with a cooling medium on the back side of the weld qualifies base metal thickness equal to or greater than the test coupon thickness with and without coolant.

QW-402.24 Qualification with a cooling medium (water, flowing gas, etc.) on the root side of a test coupon weld that is welded from one side qualifies all thicknesses of base metal with cooling medium down to the thickness of the test coupon at the root or  $\frac{1}{2}$  in. (13 mm), whichever

**QW-402.25** A change from lap joint to groove welding, and vice versa.

**QW-402.26** A reduction of more than 5 deg in the edge preparation bevel angle for groove welds.

LIE LWO DASE HIELAIS WEIGEG TO HISEH.

QW-403.2 The maximum thickness qualified is the thickness of the test coupon.

#### QW-403.3

(a) For full penetration single-sided welds without backing where the verification of penetration can be made, an increase of more than 20% in base metal thickness when the test coupon thickness is less than or equal to 1 in. (25 mm), and more than 10% in base metal thickness when the test coupon thickness is greater than 1 in. (25 mm).

(b) For all other welds, an increase of more than 10% in base metal thickness when the test coupon thickness is less than or equal to 1 in. (25 mm), and more than 5% in base metal thickness when the test coupon thickness is greater than 1 in. (25 mm).

**QW-403.4** Welding procedure qualifications shall be made using a base metal of the same type or grade or another base metal listed in the same group (see Table QW/QB-422) as the base metal to be used in production

**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 t

a change in type of coating as s

e in the kness o DELETED

**QW-403.22** A change in the ceeding 10% of the thickness o qualified.

**QW-403.23** A change in bas the range qualified in Table QW

**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.

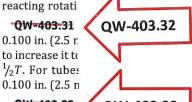
**QW-403.28** A change to another base metal type, grade, or UNS number.

**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%

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

(b) beyond the minimum and maximum thickness or thickness trar st coupon for self-



I wall thickness of tube wall thickness rease it to less than kness greater than ion test is required.

tube or tubeshimaterial is par in the P-Number or A-Number or in the nominal composition of the tubesheet cladding or control of the tubesheet cladding or cont

QW-403.34 ness or diamet wall thickness

fied tube wall thick- (19) 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.