CASTI

Codes and Standards Training Institute

Connecting-the-Codes from Temper Bead Welding to the ASME Codes, CSA Codes and the NBIC

20161018

CONNECTING-THE-CODES©
FROM
TEMPER BEAD WELDING
TO THE
ASME CODES, CSA CODES AND THE NBIC

Temper Bead Welding (TBW) is utilized as a welding technique when a carbon steel, low alloy steel, or alloy steel is designed to be used in the as-welded condition or when a post weld heat treatment (PWHT) is impractical. *Temper Bead Welding* and *Temper Bead* are not defined in AWS A3.0/3.0M; however, temper bead welding is defined in ASME Section IX as follows.

> ASME Section IX – QG-109 Definitions
>
> *temper bead welding*: a weld bead placed at a specific location in or at the surface of a weld for the purpose of affecting the metallurgical properties of the heat-affected zone or previously deposited weld metal. The bead may be above, flush with, or below the surrounding base metal surface. If above the base metal surface, the beads may cover all or only part of the weld deposit and may or may not be removed following welding.

Furthermore, ASME IX introduced rules for TBW in the 2004 Edition. The rules are found in Article II, QW-290.

Connecting-the-Codes©: ASME Sec. IX – QW-290 Temper Bead Welding

QW-290 provides rules for qualifying temper bead weld procedures and directs the code user to additional Code paragraphs for temper bead welding.

> **QW-290 TEMPER BEAD WELDING**
> When the applicable Code Section specifies the use of this paragraph for temper bead welding, QW-290.1 through QW-290.6 shall apply.

TBW is a controlled deposition technique that requires the welder to place size-controlled weld beads at specific intervals, being mindful that the placement of a second weld bead will affect the properties of the first weld bead and its associated heat affected zone (HAZ). The Section IX Code cautions its users that both bead size and placement are critical parameters to ensure successful TBW- see code paragraph QW-410.63. The required overlap, in accordance with Section IX, is between 25% and 75%.

Achieving the required overlap is not a simple task for a welder. Figure 1 shows the top view of three different welds that were completed by an experienced welder. Each of these three welds does not meet the requirements of Section IX paragraph 410.63.

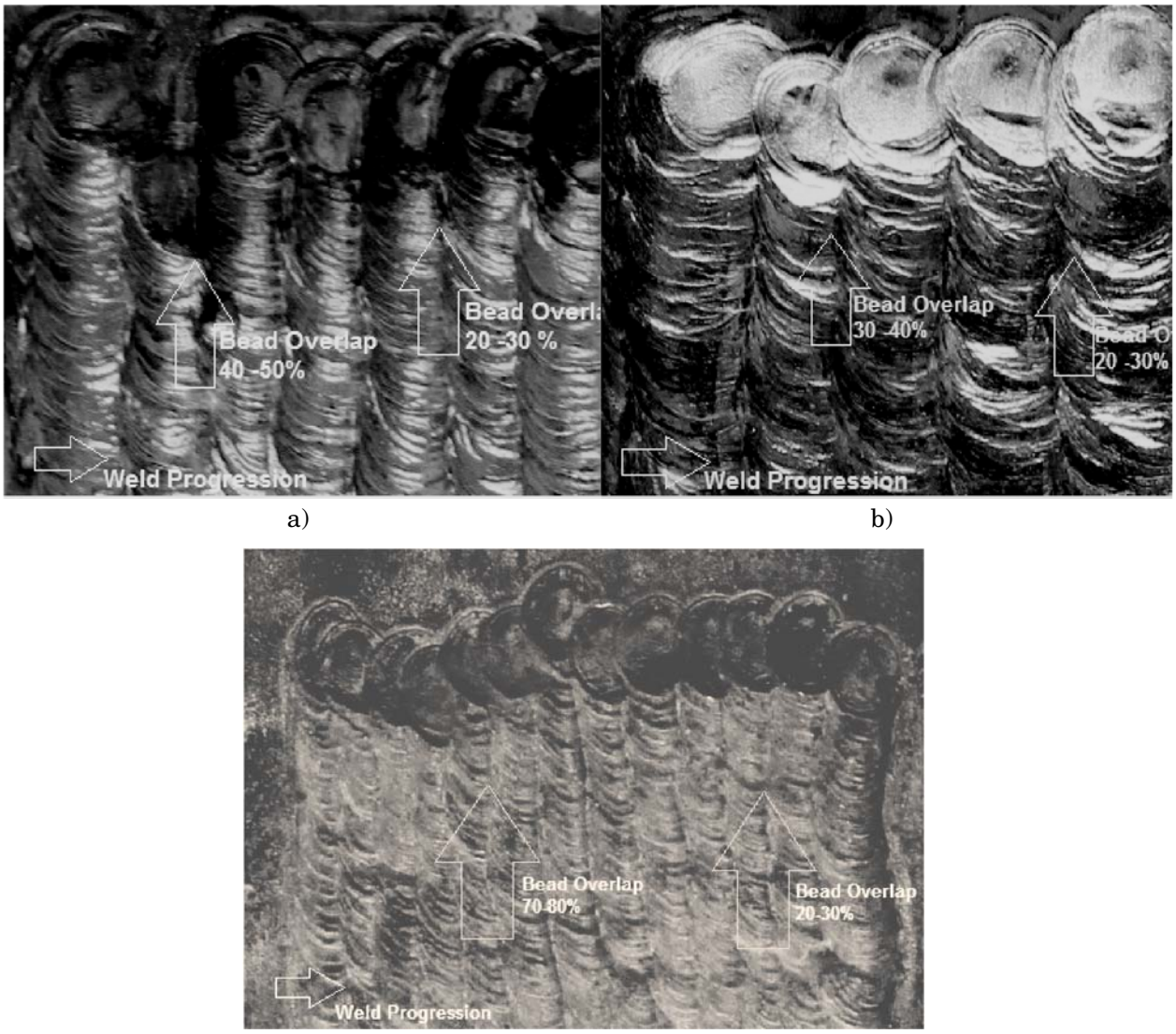


Figure 1 Top view of TBW samples: a) between 20% and 50% bead overlap; b) between 20% and 40% bead overlap; c) between 20% and 80% bead overlap.

Photos courtesy of ASME[1].

1 Meszaros, K., Vrolyk, C., Pepin, J., Yarmuch, M, Mah-Paulson, T. (2012, September). The Effects of Temper Bead Welding Technique on Weld Integrity for In-Service Welding of Carbon Steels. Paper presented at the Proceedings of the 9th International Pipeline Conference, Calgary, Alberta (p563-570). Ohio, ASME: American Society of Mechanical Engineers.

Placement of the final weld bead during temper bead welding is critical. The welder must be very careful to place the final bead so that the heat affected zone is contained within the weld metal and heat affected zone of the preceding layer. If the bead placement is incorrect, a region with elevated hardness may form at the weld toe. This region is identified, by white arrow, in Figure 2 and Figure 3. To demonstrate the hardness level that can be achieved in this region, Figure 4 shows hardness testing of 4 welds. It can be seen that the hardness at the fusion line can be as high as approximately 440Hv10.

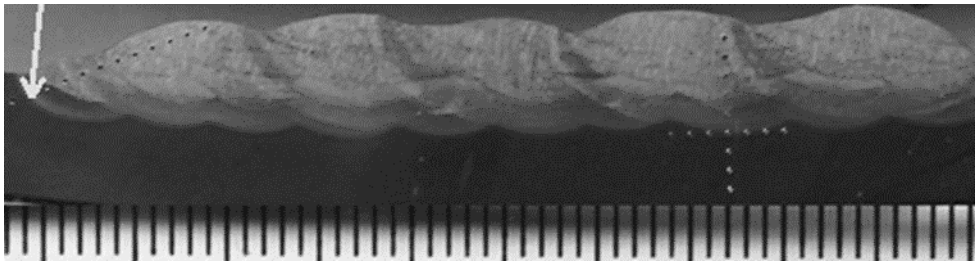


Figure 2: Cross-sectional view of a TBW test coupon.
Photo courtesy of ASME[1].

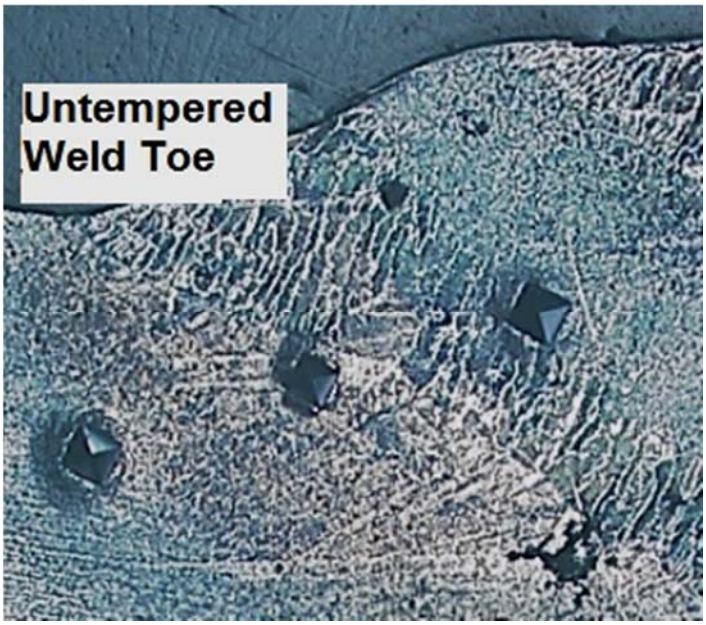


Figure 3: Untempered weld toe following TBW. 35x, zoomed in.
Photo courtesy of ASME[1].

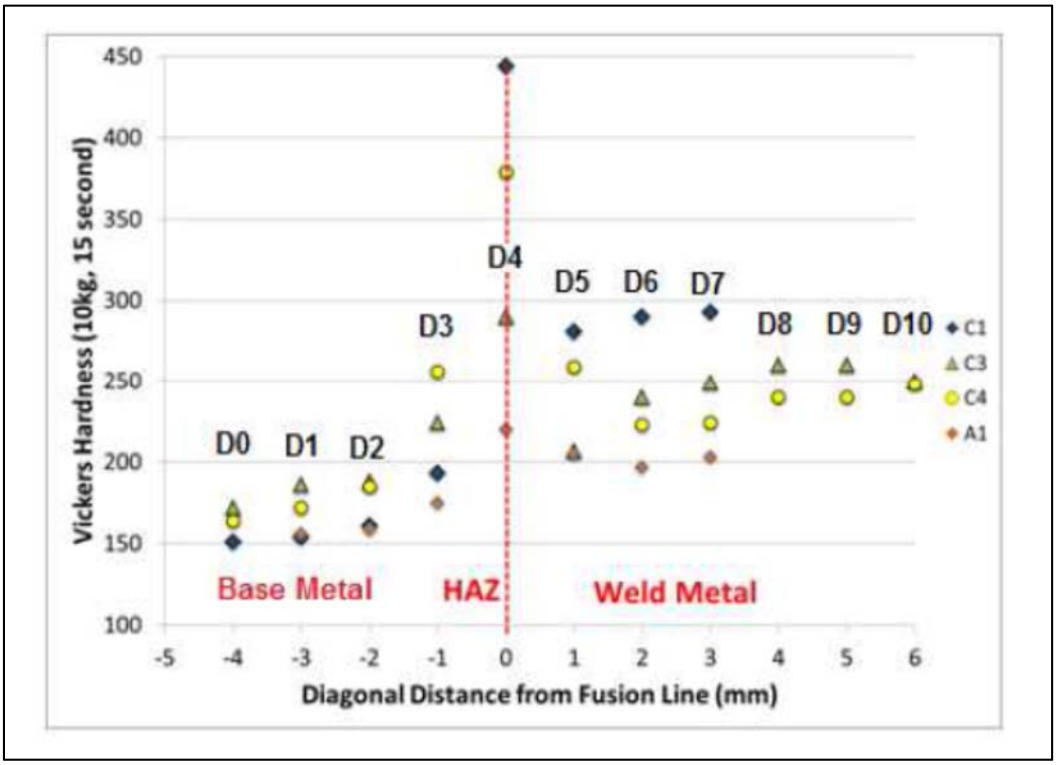


Figure 4: Diagonal hardness traverse approaching the weld toe of a TBW coupon.
Image courtesy of ASME[1].

Temper Bead Welding and Industry Codes and Standards

ASME IX

Connecting-the-Codes©: ASME Sec. IX – QW-290 Upgrading An Existing WPS to Include TBW

QW-290.1 discusses how a code user may upgrade an existing WPS to include a PQR for TBW.

> **QW-290.1 Basic Qualification and Upgrading Existing WPSs.**
> All WPSs for temper bead welding of groove and fillet weld shall be qualified for groove welding in accordance with the rules in QW-202 for qualification by groove welding or the rules in QW-283 for welds with buttering. WPSs for overlay shall be qualified in accordance with QW-214 or QW-216. Once these requirements and any additional qualification requirements of the applicable construction code have been satisfied, then it is necessary only to prepare an additional test coupon using the same procedure with the same essential and, if applicable, the supplementary essential variables with the coupon long enough to obtain the required temper bead test specimens.

An existing procedure, in accordance with these rules, may be supplemented with an additional TBW test coupon to be compliant with QW-290 for TBW. Alternately, a new procedure may be qualified that incorporates the required testing for both groove, fillet, buttered, or overlay welding in addition to the test requirements for TBW.

Connecting-the-Codes©: ASME Sec. IX – QW-290 Upgrading An Existing WPS to Include TBW

QW-290.1 discusses how a qualified WPS for TBW addresses changes to essential variables.

> **QW-290.1 Basic Qualification and Upgrading Existing WPSs.**
> When a procedure has been previously qualified to satisfy all requirements including temper bead welding, but one or more temper bead welding variables is changed, then it is necessary only to prepare an additional test coupon using the same procedure with the same essential and, if applicable, the supplementary essential variables and the new temper bead welding essential variable(s) with the coupon long enough to obtain the required test specimens.

If any essential variables that are only pertinent to TBW change, then only a supplemental TBW coupon test is required to qualify the TBW procedure.

Connecting-the-Codes©: ASME Sec. IX – QW-290 TBW Process Restrictions

QW-290.2 discusses welding process restrictions for TBW.

> **QW-290.2 Welding Process Restrictions.**
> Temper bead welding is limited to SMAW, GTAW, SAW, GMAW (including FCAW), and PAW. Manual and semiautomatic GTAW and PAW are prohibited, except for the root pass of groove welds made from one side and as described for making repairs to temper bead welds in QW-290.6.
>
> The essential variables listed in Table QW-290.4 apply in addition to the variables applicable for the process(es) qualified as given in QW-250. When impact testing is the basis for acceptance, the supplementary essential variables of QW-250 applicable to the process being qualified shall apply. When these variables conflict with or provide more stringent limitations than those of QW-250, these variables shall govern.

QW-290.2 restricts the welding processes that may be used to complete TBW. Manual and semi-automatic GTAW and PAW are not permitted for TBW because controlling the weld bead size in these operations is difficult, and uncontrolled bead size can lead to unknown and/or undesirable weldment properties.

Connecting-the-Codes©: ASME Sec. IX – QW-290 TBW Process Restrictions

QW-290.2 give welding process restrictions for TBW and state that the QW-250 tables are invoked.

> **QW-290.2 Welding Process Restrictions.**
> The essential variables listed in Table QW-290.4 apply in addition to the variables applicable for the process(es) qualified as given in QW-250. When impact testing is the basis for acceptance, the supplementary essential variables of QW-250 applicable to the process being qualified shall apply. When these variables conflict with or provide more stringent limitations than those of QW-250, these variables shall govern.

For TBW, there are two types of essential variables, based on hardness or impact test acceptance criteria that can be utilized: hardness test or impact test.

Table QW-290.4
Welding Variables for Temper Bead Procedure Qualification

Paragraph		Brief of Variables	Hardness Test Essential Variables	Impact Test Essential Variables	Nonessential Variables
QW-402	.23	+ Fluid backing	X		
	.24	+ Fluid backing		X	
QW-403	.25	P-No. or Gr. No.		X	
	.26	> Carbon equivalent	X		
	.27	> T	X		
QW-404	.51	Storage			X
	.52	Diffusible hydrogen			X
QW-406	.8	> Interpass temperature		X	
	.9	< Preheat temperature	X		
	.10	Preheat soak time			X
	.11	Postweld bakeout			X
QW-408	.24	Gas moisture			X
QW-409	.29	Heat input ratio	X	X	
QW-410	.10	Single to multiple electrode	X	X	
	.58	– Surface temper beads	X	X	
	.59	Type of welding	X	X	
	.60	+ Thermal preparation	X	X	
	.61	Surface bead placement	X	X	
	.62	Surface bead removal method			X
	.63	Bead overlap	X	X	
	.65	± Grinding	X	X	

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

Connecting-the-Codes©: ASME Sec. IX – Preheat

QW-406.9 shows that the minimum preheat during production must be what was utilized during TBW PQR qualification.

Table QW-290.4
Welding Variables for Temper Bead Procedure Qualification

Paragraph		Brief of Variables	Hardness Test Essential Variables	Impact Test Essential Variables	Nonessential Variables
QW-406	.9	< Preheat temperature	X		

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

QW-406.9

A decrease in the preheat temperature from that achieved on the test coupon and recorded on the PQR. The preheat temperature shall be measured and recorded separately for each tempering weld bead layer and, if any, for the surface weld bead layer(s). The WPS shall specify the minimum preheat temperature limits for each tempering bead layer separately and for the surfacing weld bead layer(s), if any.

QW-406.9 states that decreasing the preheat temperature from what was qualified could affect the weldment hardness. This paragraph also adds that each temper bead layer must have the preheat temperature recorded, further underscoring the effects that preheat and, consequently, the cooling rate has on the resultant weldment hardness.

QW-410.61 describes an essential variable for both hardness test and impact test essential variables related to surface bead placement.

Table QW-290.4
Welding Variables for Temper Bead Procedure Qualification

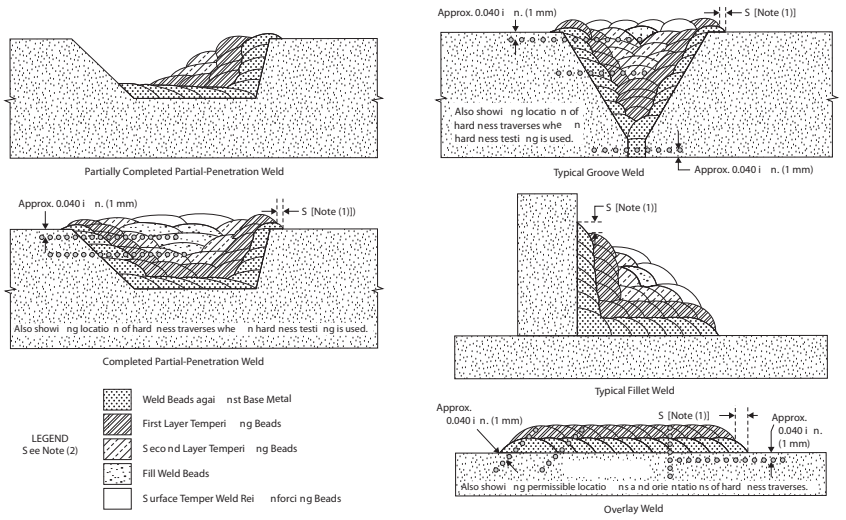
Paragraph		Brief of Variables	Hardness Test Essential Variables	Impact Test Essential Variables	Nonessential Variables
QW-410	.61	Surface bead placement	X	X	

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

QW-410.61

The distance, S, from the toe of the weld to the edge of any tempering bead shall be limited to the distance measured on the test coupon ±1/16 in. (±1.5 mm) (see Figure QW-462.12)… temper reinforcing beads shall not be permitted to touch the toe of the weld.

Figure QW-462.12
Nomenclature for Temper Bead Welding



GENERAL NOTES:
(a) Weld beads shown above may be deposited in any sequence that will result in placement of the beads as shown.
(b) Surface temper reinforcing beads may cover the entire weld surface, or may only be placed at the toe of the weld; they may or may not be mechanically removed.

NOTES:
(1) The distance, S, is measured from the toe of the weld to the edge of the temper beads. Measurements shall be made parallel to the base metal surface.
(2) Beads near the finished surface may be both tempering beads and surface temper reinforcing beads.

The code is emphasizing the importance of maintaining consistent bead size and placement during TBW.

Connecting-the-Codes©: ASME Sec. IX – TBW Test Coupon Evaluation- Hardness Testing

QW-290.5 provides instructions for the hardness testing of TBW coupons.

QW-290.5 Test Coupon Preparation and Testing.

(c) When hardness testing is specified by a Construction Code or Design Specification or no specific testing is required, measurements shall be taken across the weld metal, heat-affected zone, and base metal using the Vickers method with a 10-kg load. Increments between measurements shall be as specified in ASTM E384…

(1) Measurements shall be taken along a line at approximately mid-plane of the thickness of the test coupon weld metal.
(2) Additional measurements shall be taken along a line approximately 0.04 in. (1 mm) below the original base metal surface…
(3) When the coupon is a full-penetration groove weld made from one side, additional measurements shall be taken along a line approximately 0.04 in. (1 mm) above the root side surface...

Hardness readings shall not exceed the hardness limits specified by the Construction Code or Design Specification.

Where hardness is not specified, the data shall be reported.

Whether the code of construction or design specification requires hardness testing or not, QW-290.5 dictates that hardness testing be reported.

QW-290.5 c) also indicates that hardness testing of full penetration groove welds qualify partial penetration groove welds, fillet welds and build up welds but that the reverse is not true. Partial penetration welds qualify only partial penetration welds.

ASME VIII Division 1

Connecting-the-Codes©: ASME Sec. VIII Div. 1 – Requirements for Postweld Heat Treatment

Part UCS-56 of Section VIII Div. 1 permits weld repairs to be made utilizing the TBW technique. UCS-56 stipulates that permissible TBW may be completed using the half bead weld repair and weld temper bead reinforcement technique.

> UCS-56 f)
> (4) In addition to the requirements of Section IX for qualification of Welding Procedure Specifications for groove welds, the following requirements shall apply: …
>
> (-c) …the repair weld method shall be limited to the half bead weld repair and weld temper bead reinforcement technique… Approximately one-half the thickness of this layer shall be removed by grinding before depositing subsequent layers. …
>
> A final temper bead weld shall be applied to a level above the surface being repaired without contacting the base material but close enough to the edge of the underlying weld bead to assure tempering of the base material heat affected zone...
>
> The final temper bead reinforcement layer shall be removed substantially flush with the surface of the base material.

UCS-56 describes temper bead welding as an acceptable alternative to PWHT, however, Section VIII Div 1 does not include a description of the technique, half bead weld repair required by (-c). A simplified description of temper bead welding is provided in the endnotes of the code document, Endnote 88.

ASME B31.1, ASME B31.3

Connecting-the-Codes©: ASME B31.1- Chapter V- Fabrication, Assembly and Erection- Welding

Welding procedure for pressure piping (ASME B31.1) are to be qualified in accordance with ASME B&PV Section IX. There is no mention in ASME B31.1 of temper bead welding or controlled deposition welding.

127.1.1 The welding processes that are to be used under this part of this Code shall meet all the test requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

127.5 Qualification

127.5.1 General. Qualification of the WPS to be used, and of the performance of welders and welding operators, is required, and shall comply with the requirements of the ASME Boiler and Pressure Vessel Code (Section IX) except as modified herein.

There are no requirements pertaining to temper bead welding described by ASME B31.1 in the 2014 Edition. Code users are directed to the requirements of the ASME Section IX code for all welding.

Connecting-the-Codes©: ASME B31.3- Chapter V- Fabrication, Assembly and Erection- Welding

Welding procedure for pressure piping (ASME B31.3) are to be qualified in accordance with ASME B&PV Section IX. There is no mention in ASME B31.3 of temper bead welding or controlled deposition welding.

328.2 Welding and Brazing Qualification Welding and brazing procedure specifications (WPSs and BPSs) to be followed in production welding shall be prepared and qualified, and welders, brazers, and operators shall be qualified as required by the ASME BPV Code, Section IX…

There are no requirements pertaining to temper bead welding described by ASME B31.3 in the 2014 Edition. Code users are directed to the requirements of the ASME Section IX code for all welding.

ASME PCC-2

Connecting-the-Codes©: ASME PCC-2 2011– Repair of Pressure Equipment and Piping

Article 2.8 of PCC-2 describes the requirements for TBW.

> Article 2.8
> Alternatives to Traditional Welding Preheat
>
> 3 DESIGN
>
> The following strategies and considerations may be permissible alternatives to the original code of construction or post-construction code preheat requirements: …
> (f) controlled deposition (temper bead) welding

PCC-2 utilizes the term controlled deposition welding to describe temper bead welding.

Connecting-the-Codes©: ASME PCC-2 2011– Repair of Pressure Equipment and Piping

Controlled deposition welding, or temper bead welding, is described by PCC-2 as an available repair technique. It is up to the standard user to identify the applicable code and to determine if temper bead welding is permissible. Examples of codes that may be applicable include ASME B&PV Section IX QW-290 as well as API 570 and ANSI NB-23.

> Article 2.8
> Alternatives to Traditional Welding Preheat
>
> 3.6 Controlled Deposition Welding
>
> (a) Use of controlled deposition (temper bead) procedures can be useful to generate fine grain heat affected zones and improve notch toughness. This method should be considered when either elevated preheat or code-required postweld heat treatment cannot be used. Rules for qualification of procedures are included in API 510, 7.2.3; ASME BPVC Section IX, QW-290; and ANSI NB-23.
>
> (b) Where similar composition weld metal is used, this method will NOT lower residual stresses. An evaluation to consider the effect of welding residual stresses should be conducted where this method is to be used.

PCC-2 permits the use of TBW as an alternative to traditional welding preheat in Article 2.8. PCC-2 also provides examples of cases where this technique should be considered as well as a caution regarding residual stress.

Other Industry Codes and Standards

API 510

Connecting-the-Codes©: API 510– Pressure Vessel Inspection

The API 510 Code provides requirements for the in-service inspection of pressure vessels. This code defines temper bead welding as a *controlled-deposition welding* technique (*CDW*). API 510 8.1.7.4.3 will be discussed separately. The description of the CDW techniques in API 510 includes both the temper bead and half bead welding techniques.

> 3 Terms, Definitions, Acronyms, and Abbreviations
> 3.1 Terms and Definitions
>
> *Controlled-Deposition Welding (CDW):* Any welding technique used to obtain controlled grain refinement and tempering of the underlying heat-affected zone in the base metal. Various controlled-deposition techniques, such as temper bead (tempering of the layer below the current bead being deposited) and half bead (requiring removal of one-half of the first layer), are included. See 8.1.7.4.3.
>
> 8.1.7.4.3.3 CDW Method (Notch Toughness Testing Required)
> …
> Refer to WRC Bulletin 412 for additional supporting technical information regarding CDW.

WRC Bulletin 412 contains a collection of research papers presented at a 1996 workshop, called "Challenges and Solutions in Repair Welding for Power and process Plants". The workshop proceedings include descriptions of inclusion of controlled deposition welding (CDW) and/ or TBW to the NBIC—current at the time of publication, description of the TBW process and its applicability to repair scenarios presented and temper bead welding of dissimilar metal weld joints.

National Board Inspection Code (NBIC): Part 3

Connecting-the-Codes©: NBIC Part 3: Repairs and Alterations- Welding and Heat Treatment

The NBIC Part 3 Code provides requirements for the repair and alteration of pressure-retaining items.

> 2.5.3 ALTERNATIVE WELDING METHODS WITHOUT POSTWELD HEAT TREATMENT
>
> d) The detailed welding methods listed in the following subsections may be used as an alternative to postweld heat treatment (PWHT).
>
> … NBIC Part 3, 2.5.3.2 thru 2.5.3.5, are methods in which the welding procedure requires the use of a temper-bead welding technique.
>
> Temper-bead welding procedure nomenclature is defined in Section IX of the ASME Boiler and Pressure Vessel Code. Typically, this technique minimizes heat input of the initial beads, thus limiting heat beyond the weld heat-affected zone (HAZ) of the base metal. Heat input shall be increased for successive beads in accordance with the rules of QW-290 for temper bead welding in ASME Section IX.
>
> The Welding Procedure and Welder Performance Qualifications shall, in all cases, be in accordance with the requirements of the latest Edition of Section IX of the ASME Boiler and Pressure Vessel Code.

The NBIC requires that welding be conducted in accordance with the applicable Code of Construction or, in accordance with the requirements of ASME B&PV Section IX.

Connecting-the-Codes©: CSA Z662: Oil and Gas Pipeline Systems

The CSA Z662 code does not specifically address temper bead welding.

> CSA Z662
> SECTION 7: Joining
> 7.2 Arc and gas welding — General
> 7.2.5 For other than partial-penetration butt welds, welding procedure specifications that are established and qualified as specified in the ASME Boiler and Pressure Vessel Code, Section IX may be used, provided that
> (a) the welder qualification tests are as specified in the ASME Boiler and Pressure Vessel Code, Section IX;
> (b) the methods of inspection and acceptance criteria for visual and nondestructive inspection of the
> production welds are as specified in ASME B31.3 with the extent of examination as specified in
> Clause 7.10.3;
> (c) the requirements of Clauses 7.2.6, 7.2.7, 7.17, and 10.13.2, whichever are applicable, and for sour service, Clauses 16.6 and 16.9.3, are additionally met; and
> (d) the piping welds
> (i) are made at a manufacturing plant or a fabrication shop remote from the final installation;
> (ii) are maintenance welds;
> (iii) are in a station;
> (iv) join pipe to components; or
> (v) join components to components.

CSA Z662 does, however, permit the code user to use procedures qualified in accordance with the ASME B&PV Section IX code, which by implication includes temper bead welding.

IN-HOUSE TRAINING

CUSTOMIZED TRAINING SOLUTIONS

ADVANTAGES OF IN-HOUSE TRAINING

CASTI's In-house training courses provide cost-effective, customized training with the convenience of being held at your facility to accommodate your staff schedules and limit travel expenses.

CASTI training imparts thorough knowledge of the most up-to-date codes, regulations, technological advances, resources, and trends to your employees. With better understanding of the important underlying principles behind codes and standards, your company will gain operational efficiencies and avoid costly errors.

CASTI can adapt the content of any of our standard open-enrollment courses to suit your requirements or we can develop a custom course specifically targeting your company's needs.

A COST EFFECTIVE TRAINING SOLUTION

CASTI's training instructors will to travel to your site to present your course. Selecting in-house training allows you to make significant financial savings on items such as staff accommodation, travel, and venue costs.

CASTI Learning Advantage (CLA) online lessons are also available to allow more content coverage; before and after classroom training dates.

INSTRUCTOR AVAILABILITY & TRAINING DATES

To avoid disappointment, CASTI recommends booking in-house training courses at least six months in advance. This will help in securing instructor availability for dates suitable to your schedule.

We welcome your no-obligation inquiry to discuss your specific training needs.

REQUEST IN-HOUSE TRAINING

For inquiries, please complete the In-House Training Request Form at:

https://www.casti.ca/pages/inHouseRequestForm

or scan the QR Code:

A CASTI representative will contact you to discuss the details of your training request as soon as possible.

Codes and Standards Training Institute (CASTI)
205–10544 106 Street NW, Edmonton AB T5H 2X6
www.casti.ca
training@casti.ca
Tel: 780-424-2552
Fax: 780-421-1308