API Ballot id# 5800
SC5 TGLP

Work Item	4246 – Field Girth Weldability Testing
Distribution-type [Ballot (vote and comment), Comment-only (review), Recirculation (comment resolution), Re-ballot, etc.]	Comment-only (review)
Document	SPEC 5L, 46th Edition
Other Impacts	None
Revision Key	Current/unchanged content in BLACK; Track Changes as: 1) Additions in underlined BLUE 2) Deletions in ~~stricken RED~~ NOTE The "******" indicates there is un-altered content above / below.

Work Item Charge:

Develop an annex for weldability testing of line pipe manufactured in accordance with API Spec 5L. The intent is to demonstrate that the line pipe is suitable for field girth welding processes.

Ballot Rationale:

The Annex will provide a standardized practice for performing weldability testing on line pipe including provisions for demonstrating properties in pipe at weld heat affected zone (HAZ).

NOTE See the ballot email notification for additional information regarding this ballot.

Line Pipe

API SPECIFICATION 5L

FORTY-SIXTH EDITION, APRIL 2018

API MONOGRAM PROGRAM EFFECTIVE DATE: MAY 1, 2019

ERRATA 1, MAY 2018

******

7 Information to be Supplied by the Purchaser

******

7.2 Additional Information

The purchase order shall indicate which of the following provisions apply for the specific order item:

……

c) Items that apply, if agreed:

……

17) field girth weldability data or tests for PSL 2 pipe (see 9.15 and Annex X);

******

9 Acceptance Criteria

******

9.15 Weldability of PSL2 Pipe

******

If agreed, weldability testing shall be in accordance with Annex X.

******

Annex X
(normative)

Field Girth Weldability Testing

X.1 Introduction

This annex specifies additional weldability testing requirements for API 5L PSL 2 pipe [see 7.2 c) 17)].

The intent of the weldability test is to verify acceptable properties in the field girth weld HAZ. This is not the field welding procedure to be used; however, such information may be used to aid the development of the field welding procedure. To this end, the pipe material should be tested to cover typical or a range of heat input energies generally utilized in subsequent pipe utilization. This document gives three options which can be selected individually to cover ranges typically used.

NOTE Depending on the welding process and procedure used during the weldability test, the effects on the properties of the pipe materials can have conflicting aims (e.g., toughness and hardness).

X.2 Additional Information to be Supplied by the Purchaser

In addition to items a) to c) as specified by 7.2, the purchase order shall also indicate which of the following provisions apply for the specific order item:

b) Items that are subject to mandatory agreement, if applicable:

1) alternate data (X.3.3.2);

2) alternate evaluation details (X.4.5.1 and X.6.1);

3) average hardness for moderate and high heat input evaluation (X.5.4.2).

c) Items that apply as prescribed, unless otherwise agreed:

1) low heat input evaluation welding process (X.4.2.2);

2) bevel configuration (X.4.2.3);

3) heat Input (X.4.2.5; X.4.3.5 and X.4.4.5);

4) moderate heat input evaluation welding process (X.4.3.2);

5) CVN Impact and CTOD acceptance criteria (X.5.2.1 and X.5.3.1);

6) hardness acceptance criteria (X.5.4.1);

7) CVN Impact and CTOD test temperature (X.6.3.1.1 and X.6.3.2.2).

d) Items that apply, if agreed:

1) material format (X.3.4.1.2);

2) purchaser approval of heat analysis (X.3.4.2.4);

3) sample heat treat condition (X.3.4.3.1);

4) material strength (X.3.4.4.1);

5) notch location at 2 or 5 mm from the fusion line (X.6.2.2.4).

X.3 Material for Weldability Test

X.3.1 Manufacturing Procedure Qualification

The pipe material shall be qualified in accordance with the manufacturing procedure qualification (see Annex B) and within the limits specified (see B.5.), as applicable.

X.3.2 Weldability Test-type

In addition to the requirements of 7.1, the purchase order shall indicate if any of the weldability test-type provisions from below apply for the specific order item:

a) low heat input evaluation,

b) moderate heat input evaluation,

c) high heat input evaluation, and/or

d) alternate evaluation.

X.3.3 Frequency

X.3.3.1 When requested by the purchaser, the weldability tests shall be conducted for each steelmaking and rolling practice.

The maximum pipe wall thickness variation from the nominal qualified shall be ± 20 %.

Pipe grades grouping shall be X52 to X60 and X65 to X70. For X80 and above, each steel grade shall be tested individually.

X.3.3.2 If agreed, the manufacturer shall supply weldability data for the type of steel concerned in lieu of performing weldability tests.

X.3.4 Material Details

X.3.4.1 Format

X.3.4.1.1 The material shall be taken from steel plate/coil or pipe.

X.3.4.1.2 If agreed, weldability tests shall be performed on the finished pipe.

X.3.4.2 Composition

X.3.4.2.1 The requirements for the chemical composition of the steels (based upon heat analysis) and, in particular, the limiting values of CE_{Pcm}, and CE_{IIW} (see Table 5, Table H.1, Table J.1, or Table N.1, whichever is applicable) have been selected to facilitate weldability.

NOTE The behavior of the steel during and after welding is dependent not only on the steel composition, but also on the hot rolling/cooling processes, welding process, heat input, pre-heat/interpass temperatures used and the conditions for preparing for, and carrying out, welding.

X.3.4.2.2 For *low* heat input evaluation, the steel shall be selected from the *high* end of the chemical composition range no *less* than 0.02 % *below* than the *maximum* carbon equivalent (CE_{IIW} or CE_{Pcm}, as applicable).

X.3.4.2.3 For *moderate* and *high* heat input evaluation, the steel shall be selected from the *low* end of the chemical composition range no *more* than 0.02 % *above* than the *minimum* carbon equivalent (CE_{IIW} or CE_{Pcm}, as applicable).

NOTE Minimum CE_{IIW} or CE_{Pcm} is not specified in this specification, so the low end of the range may be based upon the actual production or the applicable purchaser supplemental specification. The maximum CE levels might be lower than specified in this specification based on manufacturer design or purchaser supplemental specification.

X.3.4.2.4 If agreed, the purchaser shall approve the heat analysis of the steel to be used for the weldability tests.

X.3.4.3 Heat Treatment Condition

If agreed, a fusion bonded epoxy (FBE) coating heat treatment may be applied either by testing the coated pipe or by simulating the FBE heat treatment by heating the test coupon (e.g., 10 minutes at 260 °C).

X.3.4.4 Material Strength

If agreed, material form the high end of strength range shall be used for weldability testing.

X.4 Test Welds

X.4.1 General

X.4.1.1 Weldability tests shall be performed by the pipe manufacturer or by agreement with an accepted vendor under their responsibility.

X.4.1.2 Heat input calculation shall be made according to Equation X.1:

$$HI = \eta \times [(V \times I \times 60) / (1000 \times v)] \quad (X.1)$$

where

HI = heat input (kJ/mm)

η = process efficiency: 0.8 for SMAW, FCAW and GMAW; 0.6 for GTAW; 1.0 for SAW

V = voltage (V)

I = amperage (A)

v = travel speed (mm/min)

X.4.1.3 The heat transfer efficiency is already considered in some welding machines output. In these cases, the heat input calculation shall be done without consider the welding process efficiency.

X.4.1.4 Wave form welding modification is not permitted for low, moderate, and high heat input options.

X.4.2 Low Heat Input Evaluation

X.4.2.1 Frequency and Orientation

At least one weld shall be produced on each steel in the 1G (flat position/roll welding) or 5G position.

X.4.2.2 Welding Process

Unless otherwise agreed, the weldability tests shall be done with a single arc process. Any welding process may be used provided the specified heat input (X.4.2.5) is achieved.

X.4.2.3 Bevel Configuration

Unless otherwise agreed, test coupons shall be prepared with angled bevel(s) on one side and a square cut (0°) bevel on the other side. Figure X.1 shows some examples.

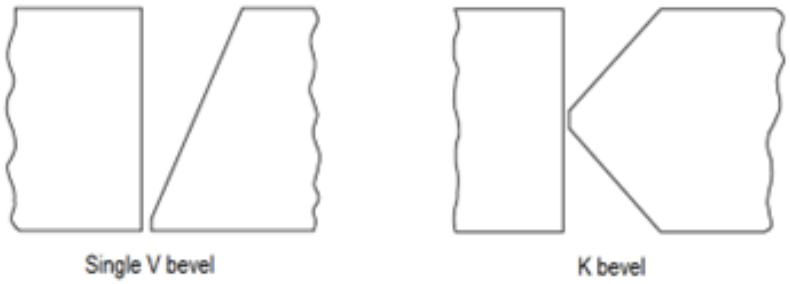


Figure X.1—Examples of Bevel Preparation

X.4.2.4 Consumables

The weld shall be fabricated using consumables that meet or exceed the minimum tensile strength of the grade.

X.4.2.5 Heat Input

Unless otherwise agreed, the tests shall be carried out with a heat input less than 0.8 kJ/mm, preheating temperature of 20 °C (± 5 °C) and maximum interpass temperature of 200 °C for all welding passes.

X.4.2.6 Coupon Dimensions

For flat welding the weld produced for each configuration shall be a minimum of 24 in. (610 mm) long using with the minimum coupon width being 12 in. (300 mm) of each section [24 in. (610 mm) for finished welded width].

For pipe welding, rings shall be a minimum of one pipe diameter or 12 in. (305 mm), whichever is shorter.

X.4.3 Moderate Heat Input Evaluation

X.4.3.1 Frequency and Orientation

At least one weld shall be produced on each steel in 1G (flat position/roll welding) or 5G position.

X.4.3.2 Welding Process

Unless otherwise agreed, the weldability tests shall be done with a single arc process. Any welding process may be used provided the specified heat input (X.4.3.5) is achieved.

X.4.3.3 Bevel Configuration

Test coupons shall be prepared with angled bevel(s) on one side and a square cut (0°) bevel on the other side. Figure X.1 shows some examples.

X.4.3.4 Consumables

The weld shall be fabricated using consumables to ensure an overmatched weld relative to the parent steel is achieved. Overmatching shall be demonstrated by mechanical testing.

X.4.3.5 Heat Input

Unless otherwise agreed, the welds shall be fabricated using a 1.5–2.0 kJ/mm heat input with a minimum preheat of 100 °C and a maximum interpass temperature of 200 °C.

X.4.3.6 Coupon Dimensions

For flat welding the weld produced for each configuration shall be a minimum of 24 in. (610 mm) long using with the minimum coupon width being 12 in. (300 mm) of each section [24 in. (610 mm) for finished welded width].

For pipe welding, rings shall be a minimum of one pipe diameter or 12 in. (305 mm), whichever is shorter.

X.4.4 High Heat Input Evaluation

X.4.4.1 Frequency and Orientation

At least one full weld shall be produced on each steel in 1G (flat position/roll welding) or 5G position.

X.4.4.2 Welding Process

The welding processes shall be SAW.

X.4.4.3 Bevel Configuration

Test coupons bevels shall be prepared to generate a near linear HAZ on one side of the joint with either a K-bevel or single-V-bevel joint preparation as shown in Figure X.1. Alternate bevel configurations may be considered if agreed, but one side of the joint shall present a near linear straight HAZ.

X.4.4.4 Consumables

The weld shall be fabricated using consumables to ensure an overmatched weld relative to the parent steel is achieved. Overmatching shall be demonstrated by mechanical testing.

X.4.4.5 Heat Input

Unless otherwise agreed, the welds shall be fabricated using a 2.5–3.0 kJ/mm heat input with a minimum preheat of 100 °C (212 °F), and a maximum interpass temperature of 250 °C.

NOTE Preheat temperature is the minimum temperature of the base material in the volume surrounding the point of welding immediately before welding is started. In a multipass weld, it is also the minimum temperature immediately before the second and subsequent passes are started. Interpass temperature is the temperature at a location near the start position of the welding arc(s) recorded immediately before initiating the next pass or passes (multi-arc processes).

X.4.4.6 Coupon Dimensions

For flat welding, the weld produced for each configuration shall be a minimum of 24 in. (610 mm) long using with the minimum coupon width being 12 in. (300 mm) of each section [24 in. (610 mm) for finished welded width].

For pipe welding, rings shall be a minimum of one pipe diameter or 12 in. (305 mm), whichever is shorter.

X.4.5 Alternate Evaluation

Details such as frequency, welding process, bevel configuration, consumables, heat input, preheat temperature, inter-pass time/temperature, and coupon dimensions shall be agreed between purchaser and manufacturer.

X.5 Acceptance Criteria

X.5.1 Tensile Testing

X.5.1.1 For low heat input evaluation, a cross weld tension test shall be carried out for information.

A failure located in the weld metal shall not be considered relevant for low heat input HAZ toughness evaluation.

NOTE The intent of the test is to gather information on HAZ performance.

X.5.1.2 For moderate and high heat input evaluation, the cross weld tension test failure location and stress-and-strain values at failure shall be reported for information.

Failures in the weld shall be considered an invalid and a replacement test performed.

X.5.2 CVN Impact Testing of HAZ

X.5.2.1 Unless otherwise agreed, the tests shall meet the requirements of 9.8.3.

X.5.2.2 If one test fails the CVN impact requirement, two additional tests may be tested. If either of these tests fails, the steel fails the prequalification test requirement.

X.5.3 CTOD Testing

X.5.3.1 Unless otherwise agreed, the acceptance criterion shall be 0.10 mm (0.0040 in.).

X.5.3.2 If only one of the initial valid CTOD tests fails to meet the required acceptance value, three additional tests shall be made.

X.5.3.3 For additional tests made according to X.5.3.2, the following apply:

a) all three additional tests shall meet the required value for the prequalification to be considered acceptable with no further testing, and

b) if there are any failures in the additional tests, the provisions in 7.1.6 and 7.1.7 of BS 7910:2019 may be utilized to address scatter in the results and determine the lower bound of representative fracture toughness.

X.5.4 Hardness

X.5.4.1 For low heat input evaluation, unless otherwise agreed, the hardness in the parent metal and HAZ shall be ≤ 350 HV10.

For sour service applications, unless otherwise agreed, the requirements of H.4.4 also apply.

For parent metal tests, individual hardness readings exceeding the applicable acceptance limit may be considered acceptable if the average of a minimum of three and maximum of six additional readings taken within close proximity does not exceed the applicable acceptance limit, and if no such individual reading exceeds the acceptance limit by more than 10 HV10 units.

Retesting is permitted if agreed.

NOTE To show weldability toughness, low hardness may not be the best to assess toughness criteria. A separate weldability test (with only partial testing) may be required to balance properties.

X.5.4.2 For moderate and high heat input evaluation, the average hardness in the parent metal relative to that in the HAZ shall be as agreed.

X.6 Inspection

X.6.1 Specific Inspection

The frequency of inspection shall be given in Table X.1. Inspection frequencies for alternate evaluation shall be agreed between purchaser and manufacturer.

Table X.1—Inspection Frequency

Type of Inspection	Type of Weldability Test	Frequency of Inspection
Cross weld tensile	Low, moderate, and high heat input evaluation	Once per test weld
HAZ CVN impact tests (X.6.2.2)	Low, moderate, and high heat input evaluation	Unless otherwise agreed, once per test weld at location 1 (see Figure X.2)
HAZ CTOD testing (X.6.2.3)	Low, moderate, and high heat input evaluation	A set of 3 specimens per test weld at location 1 (see figure X.2)
Hardness traverse testing (X.6.2.4.1)	Low heat input evaluation	Two tests per test weld
Hardness mapping (X.6.2.4.2)	Moderate and high heat input evaluation	Two hardness map per test weld
Non-destructive inspection (X.7)	Low, moderate, and high heat input evaluation	Each test weld

X.6.2 Samples and Test Pieces for Mechanical Tests

X.6.2.1 General

X.6.2.1.1 For low, moderate, and high heat input evaluation, the tensile, CVN impact, and hardness tests, the samples shall be taken, and the corresponding test pieces shall be prepared, in accordance with the applicable reference standard in this specification.

X.6.2.1.2 For alternate evaluation, unless otherwise agreed such tensile, CVN impact and hardness tests shall be taken and corresponding test pieces shall be prepared, in accordance with the applicable reference standard in this specification.

X.6.2.1.3 Samples and test pieces for the various types of tests shall be taken according to the supplementary details in 10.2.3.2, 10.2.3.3, 10.2.4, and X.6.2.2.1 to X.6.2.4.

X.6.2.2 CVN Impact Tests

X.6.2.2.1 The set of three specimens shall be cut from a welded plate or pipe.

X.6.2.2.2 For low heat input evaluation, a notch shall be located at mid-thickness at location 1 (CGHAZ) of the welded side with 0° bevel as defined in Figure X.2.

X.6.2.2.3 For moderate and high heat input evaluation, the axis of the notch shall be placed as close as practicable to the fusion line (location 1) of the outside weld bead similar to Figure X.2.

X.6.2.2.4 If agreed, additional sets of three specimens may be notched at the location 2 and/or 3 (2 mm or 5 mm from the fusion line) of Figure X.2.

X.6.2.3 CTOD Tests

X.6.2.3.1 CTOD test specimens shall be prepared in accordance with ISO 15653 and ISO 12135 with dimensions of B x 2B or B x B for smaller diameters, where B is equal the thickness of the specimen.

X.6.2.3.2 CTOD specimens shall be notched and fatigue pre-cracked through-thickness across the CGHAZ region as specified in Figure X.2 (location 1).

X.6.2.3.3 There shall be at least 3 valid tests per condition. The tests shall also comply with the validity criteria as specified in the relevant test standard.

X.6.2.3.4 The location of notch and fatigue pre-crack shall be confirmed by metallography both before and after testing and shall be on the side with the 0° bevel.

For the coarse grain HAZ (CGHAZ) notch, at least 15 % of the central ⅔ of the section thickness should be coarse grained HAZ (CGHAZ) material.

The fusion line shall be considered part of the weld metal but not be included in the determination of % CGHAZ sampled.

NOTE The 15 % of sampled CGHAZ need not be continuous.

X.6.2.4 Hardness Test

X.6.2.4.1 Low Heat Input Evaluation

X.6.2.4.1.1 In plate welding, two specimens shall be cut at the $^1/_3$ and $^2/_3$ length of the weld.

X.6.2.4.1.2 For pipe ring welding, two specimens shall be extracted.

X.6.2.4.1.3 For both X.6.2.4.1.1 and X.6.2.4.1.1 above, the hardness specimens shall be taken at least 300 mm (12 in.) apart.

X.6.2.4.1.4 For each metallographic cross-sections, a hardness survey shall be conducted according to Figure X.3, but all indents may not be possible due to wall thickness limitations (< 10 mm).

X.6.2.4.2 Moderate and High Heat Input Evaluation

X.6.2.4.2.1 Two specimens shall be extracted at $^1/_3$ and $^2/_3$ length of the weld.

X.6.2.4.2.2 A hardness map shall be taken through the thickness across at least 2 mm from fusion line of the weld (weld side), HAZ and at least 5 mm into the parent metal (Figure X.4) permitting the generation of a visual hardness characterization in the HAZ region (Figure X.5).

X.6.3 Mechanical Testing Methods

X.6.3.1 CVN Impact Testing

Unless otherwise agreed, the CVN impact test temperature shall be 0 ˚C (+32 ˚F).

X.6.3.2 CTOD Testing

X.6.3.2.1 CTOD testing shall be carried out in accordance with ISO 12135, ISO 15653, ASTM E1820, or BS 7448-1.

X.6.3.2.2 Unless otherwise agreed, test temperature shall be 0 ˚C (+32 ˚F).

NOTE Tests conducted at lower temperature may be used and evaluated to the same criteria at the manufacturer's discretion.

X.6.3.2.3 Sectioning of CTOD samples should be made following testing, to ensure sampling and notching at the required areas.

Pre- and post-testing macrographs shall be supplied to confirm the pre-crack and crack straightness and location at the desired HAZ region.

X.6.3.3 Hardness

X.6.3.3.1 Hardness testing according to Figure X.3 shall be performed using the Vickers test in accordance with ISO 6507-1 or ASTM E92 with a 10 kg load or less, if agreed.

X.6.3.3.2 Microhardness testing according to Figures X.4 and X.5 shall be performed using the Vickers test in accordance with ISO 6507-1 or ASTM E92.

X.7 Nondestructive Inspection

Each test weld shall be inspected by visual, and UT or radiographic testing and the weld shall satisfy the acceptance criteria of the visual and NDT requirements of this specification prior to being sent for sampling/mechanical testing.

X.8 Reporting

The final report shall include, as a minimum, the following:

a) welding procedure specifications,

NOTE Including, for example, welding parameters, heat input, pre-heat and inter-pass temperatures, fit-up configurations, etc,

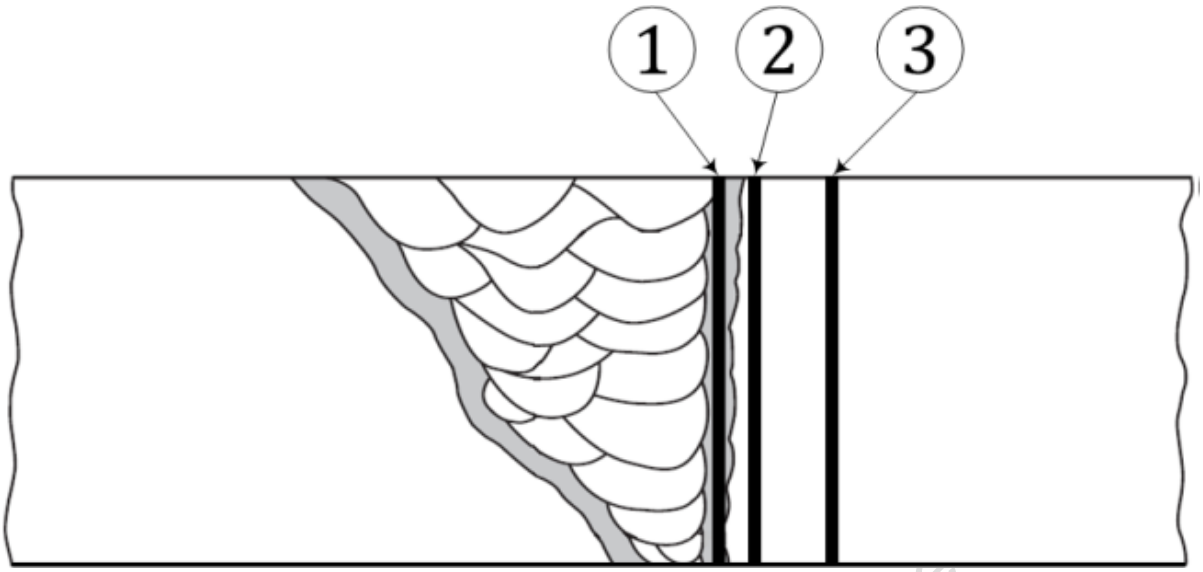
b) procedure qualification records,

c) mill certificates of plate or pipe material used, including as a minimum the heat and product analysis,

d) NDT and mechanical test results, including any failures,

e) specified macrographs and micrographs (if any), and

~~a)~~f) interpretation of results (if required).



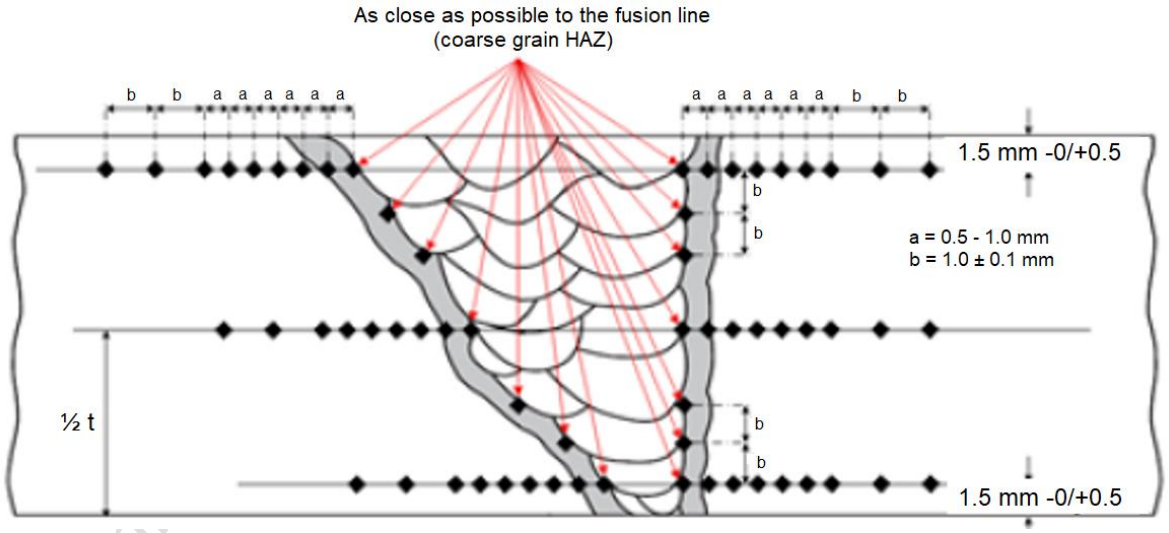
Key

[1] In the coarse grain HAZ (CGHAZ) − to be determined by metallography.

[2] At 2 mm from the fusion line.

[3] At 5 mm from the fusion line.

Figure X.2—CVN Impact and CTOD Test Locations



* In the HAZ, indentions shall be made along the traverse for each 0.5–1.0 mm (as close as possible according to the hardness specification to ensure indention is made into unaffected material).

Figure X.3—Hardness Traverse for Low Heat Input Evaluation

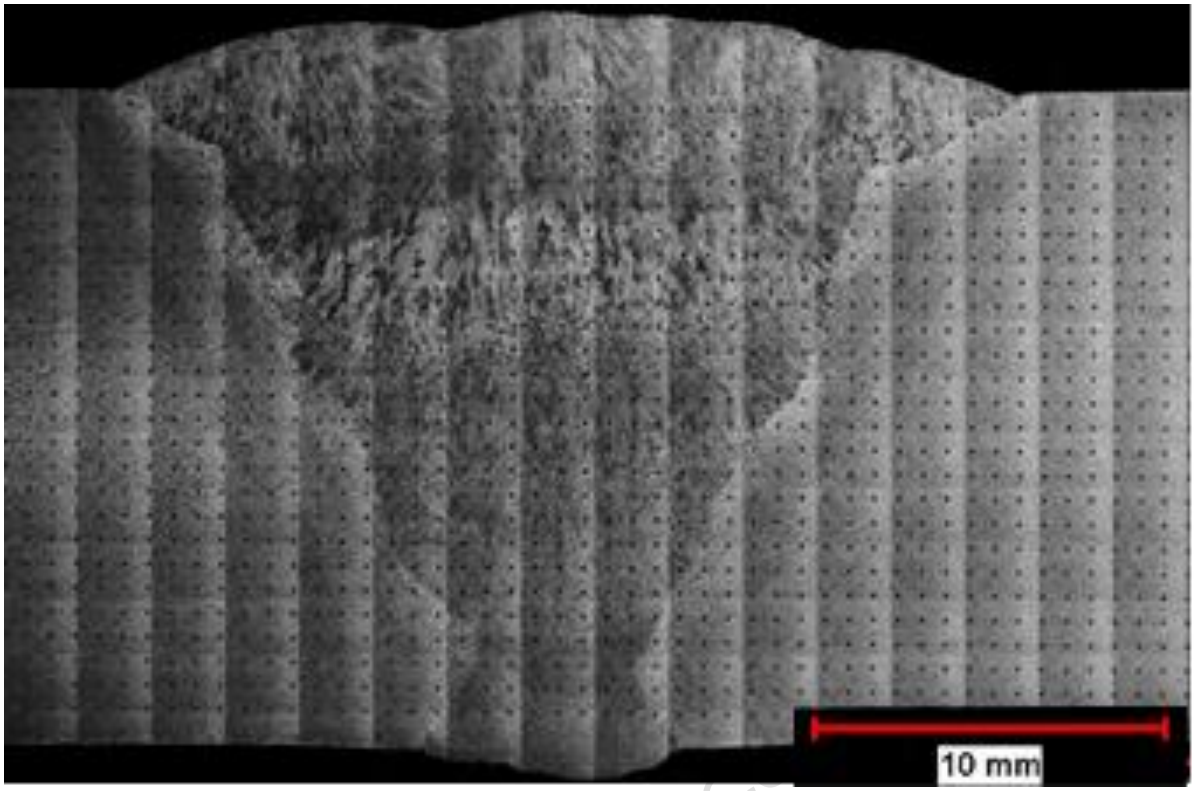


Figure X.4—Hardness Mapping for Moderate and High Heat Input Evaluation

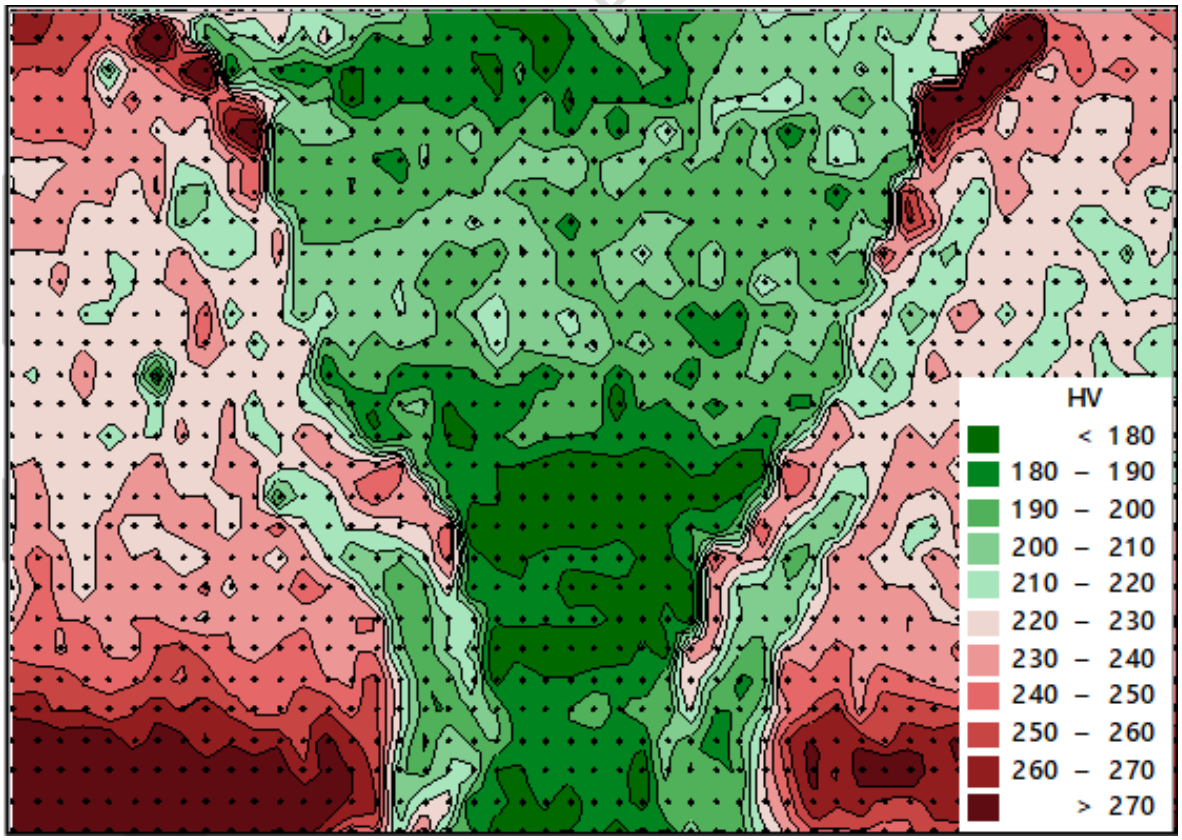


Figure X.5—Visual Characterization of Hardness Mapping for Moderate and High Heat Input Softening Evaluation

Bibliography

******

[34] BS 7910, *Guide to methods for assessing the acceptability of flaws in metallic structures*, 2019

[35] API Recommended Practice 2Z, *Preproduction Qualification for Steel Plates for Offshore Structures*, 3rd Edition

[36] IOGP S-616, *Supplementary Specification to API Specification 5L and ISO 3183 Line Pipe*, 2019