API Ballot #6206
SC5 TGLP

Work Item Number	4246
Title of Work Item	Field Girth Weldability Testing Pipe
Type of Distribution [Voting and Comment, Comment-only, Comment Resolution (recirculation), Re-ballot, Re-Re-ballot, etc.]	Initial ballot (voting and commenting) *Note a comment-only ballot (#5800) was previously distributed.*
Impacted Documents	Spec 5L, 46th Edition
Revision Key	Current/unchanged content in BLACK; Track Changes as: 1) Additions in BLUE 2) Deletions in 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).

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Line Pipe

API SPECIFICATION 5L

FORTY-SIXTH EDITION, APRIL 2018

API MONOGRAM PROGRAM EFFECTIVE DATE: MAY 1, 2019

ERRATA 1, MAY 2018

(Comment Only) Draft—For Committee Review

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7 Information to be Supplied by the Purchaser

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

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9 Acceptance Criteria

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9.15 Weldability of PSL2 Pipe

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

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Annex B
(normative)

Manufacturing Procedure Qualification for PSL 2 Pipe

B.5 Manufacturing Procedure Qualification Tests

B.5.4 If agreed, weldability test shall be in accordance with Annex X. ~~The purchaser may ask for characteristic data on other properties (e.g. weldability) of the product.~~

~~NOTE Purchaser requests for weldability data on particular steel grades can require specific weldability testing to be conducted; in such instances, it is the responsibility of the purchaser to supply the manufacturer with details of the welding processes and parameters for which weldability data are required; it is important to consider weldability testing of newly developed steel grades such as L690 or X100 and L830 or X120 where data are otherwise unavailable.~~

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Annex X
(normative)

Girth Weldability Testing

X.1 Introduction

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

The intent of the weldability test is to verify if acceptable properties in the field girth weld HAZ are obtainable. 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 four 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.3.3.4);

   2) alternate evaluation details (X.4.3 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) pipe grades grouping (X.3.3.3);

   2) welding process (X.4.1.6);

   3) heat Input (X.4.2.1; X.4.2.2 and X.4.2.3);

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

   5) hardness acceptance criteria (X.5.4.1);

   6) CVN Impact and CTOD test temperature (X.6.3.1 and X.6.3.2.2);

   7) Load for microhardness test (X.6.3.3.2).

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);

   4) material strength (X.3.4.4);

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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;

d) alternate evaluation.

X.3.3 Applicability

X.3.3.1 The weldability tests shall be conducted for each applicable delivery condition (Table 3)

X.3.3.2 The maximum pipe wall thickness variation from the nominal qualified shall be ± 25 %.

X.3.3.3 Unless otherwise agreed, pipe grades grouping shall be X52 to X56 and for X60 and above, each steel grade shall be tested individually.

X.3.3.4 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

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, pipe forming, welding process, heat input, pre-heat/interpass temperatures used and the conditions for preparing for, and carrying out, welding.

X.3.4.2.1 For *low* heat input evaluation, the steel shall be selected from the chemical composition range no *less* than 0.02 % below than the maximum carbon equivalent CE_{Pcm} or no less than 0.03 % below than the maximum carbon equivalent CE_{IIW} based on heat analysis.

X.3.4.2.2 For *moderate* and *high* heat input evaluation, the steel shall be selected from the chemical composition range no *more* than 0.02 % above than the minimum carbon equivalent CE_{Pcm} or no more than 0.03 % above than the minimum carbon equivalent CE_{IIW} based on heat analysis.

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

X.3.4.2.3 If both moderate/high and low heat input tests are required, the purchaser and manufacturer shall agree on acceptable composition ranges.

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

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X.3.4.3 Heat Treatment Condition

If agreed, a heat treatment may be applied to the plate/coil/pipe to simulate the thermal history of the pipe coating.

X.3.4.4 Material Strength

If agreed, material from 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 the manufacturer's 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 controlled welding is only permitted for alternate evaluation (X.3.2d).

X.4.1.5 Frequency and Orientation

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

X.4.1.6 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.4.2.1, X.4.2.2 or X.4.2.3, as applicable) is achieved.

X.4.1.7 Bevel Configuration

The test coupon shall be prepared with at least one square cut (0°) bevel (for testing). The other side may be prepared with angled or square bevel(s) such as the examples shown in Figure X.1.

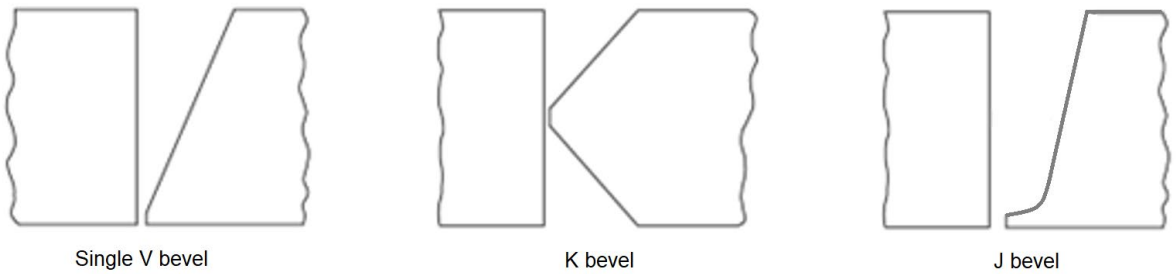

Figure X.1—Examples of Bevel Preparation

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X.4.1.8 Consumables

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

X.4.1.9 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 length of one pipe diameter or 12 in. (305 mm), whichever is shorter.

X.4.2 Heat Input

X.4.2.1 Low Heat Input Evaluation

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.4.2.2 Moderate Heat Input Evaluation

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.4.2.3 High Heat Input Evaluation

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 300 °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.4.3 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 ultimate tensile strength at failure shall be reported for information.

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

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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 from the same location. 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 minimum 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

NOTE To show weldability toughness, low hardness may not be the best to assess toughness criteria.

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.

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. Retesting is permitted if 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.

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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, one set of 3 specimens 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

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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, the 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.6.2.3 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.

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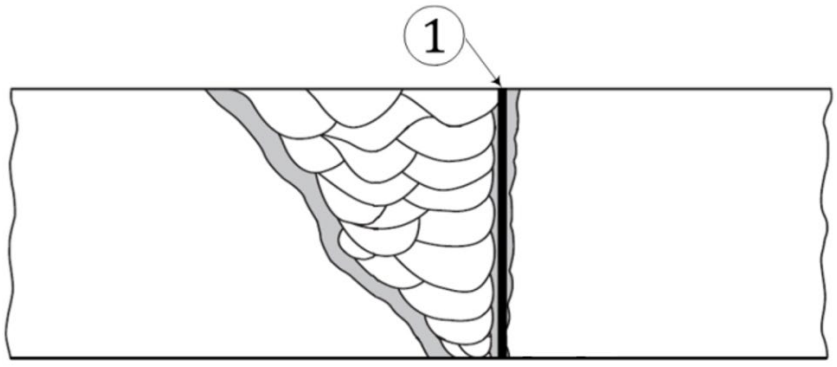
For the coarse grain HAZ (CGHAZ) notch, at least 15 % of the central ⅔ of the section thickness should be coarse grained HAZ (CGHAZ) material.

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.



Key

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

Figure X.2—CVN Impact and CTOD Test Locations

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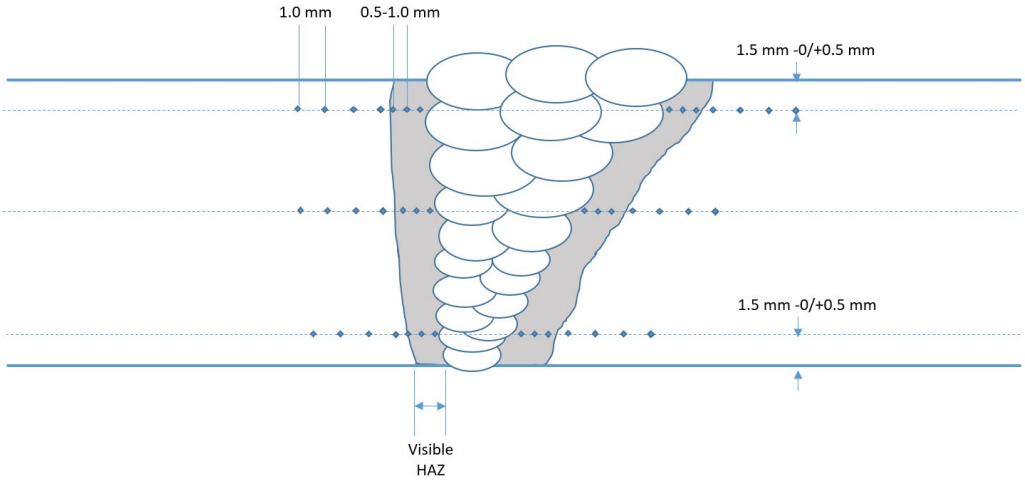
X.6.2.4 Hardness Test

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, at least 300 mm apart.

X.6.2.4.1.2 For pipe ring welding, two specimens shall be extracted at 180° apart.

X.6.2.4.1.3 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).



* 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).

** The first indentation in the HAZ shall be placed as close to the fusion line as possible and with a maximum distance of 0.5 mm between the centrepoint of the indentation and the fusion line.

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

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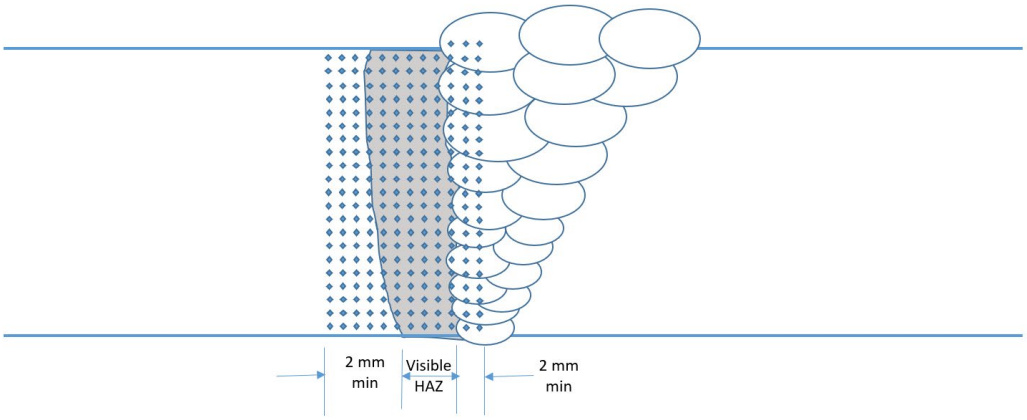
X.6.2.4.2 Moderate and High Heat Input Evaluation

X.6.2.4.2.1 For plate welding, two specimens shall be extracted at 1/3 and 2/3 length of the weld, at least 300 mm apart. For pipe ring welding, two specimens shall be extracted at 180° apart.

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



* Spacing and number of indentations may not be to scale.

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

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.

X.6.3.3.2 Microhardness testing according to Figure X.4 shall be performed using the Vickers test in accordance with ISO 6507-1 or ASTM E92. Unless otherwise agreed, the hardness load shall be 0.5 kg with an approximate 0.5mm spacing.

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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) welding details,

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

f) interpretation of results (if required).

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