

# Welding of Pipelines and Related Facilities

API STANDARD 1104  
TWENTY-FIRST EDITION, SEPTEMBER 2013

ERRATA 1, APRIL 2014  
ERRATA 2, JUNE 2014  
ERRATA 3, JULY 2014  
ERRATA 4, NOVEMBER 2015  
ERRATA 5, SEPTEMBER 2018  
ADDENDUM 1, JULY 2014  
ADDENDUM 2, MAY 2016



AMERICAN PETROLEUM INSTITUTE

**Date of Issue:** September 2018

**Affected Publication:** API Standard 1104, *Welding of Pipelines and Related Facilities*, 21st Edition, September 2013

## **Errata 5**

*Table of Contents: There were several incorrect page numbers in the table of contents. These have been corrected, and a new table of contents has been inserted.*

## Special Notes

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

Neither API nor any of API's employees, subcontractors, consultants, committees, or other assignees make any warranty or representation, either express or implied, with respect to the accuracy, completeness, or usefulness of the information contained herein, or assume any liability or responsibility for any use, or the results of such use, of any information or process disclosed in this publication. Neither API nor any of API's employees, subcontractors, consultants, or other assignees represent that use of this publication would not infringe upon privately owned rights.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any authorities having jurisdiction with which this publication may conflict.

API publications are published to facilitate the broad availability of proven, sound engineering and operating practices. These publications are not intended to obviate the need for applying sound engineering judgment regarding when and where these publications should be utilized. The formulation and publication of API publications is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

Classified areas may vary depending on the location, conditions, equipment, and substances involved in any given situation. Users of this Standard should consult with the appropriate authorities having jurisdiction.

Users of this Standard should not rely exclusively on the information contained in this document. Sound business, scientific, engineering, and safety judgment should be used in employing the information contained herein.

All rights reserved. No part of this work may be reproduced, translated, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, NW, Washington, DC 20005.

*Copyright © 2013 American Petroleum Institute*

## Foreword

This standard was prepared by a formulating committee that included representatives of the API, the American Gas Association (AGA), the Pipe Line Contractors Association (PLCA), the American Welding Society (AWS), and the American Society for Nondestructive Testing (ASNT), as well as representatives of pipe manufacturers and individuals associated with related industries.

The purpose of this standard is to present methods for the production of high quality welds through the use of qualified welders using approved welding procedures, materials, and equipment. Its purpose is also to present inspection methods to ensure the proper analysis of welding quality through the use of qualified technicians and approved methods and equipment. It applies to both new construction and in-service welding.

The use of this standard is entirely voluntary and is intended to apply to welding of piping used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, and nitrogen and, where applicable, to distribution systems.

This standard represents the combined efforts of many engineers who are responsible for the design, construction, and operation of oil and gas pipelines, and the committee appreciatively acknowledges their wholehearted and valuable assistance.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this publication or comments and questions concerning the procedures under which this publication was developed should be directed in writing to the Director of Standards, American Petroleum Institute, 1220 L Street, NW, Washington, DC 20005. Requests for permission to reproduce or translate all or any part of the material published herein should also be addressed to the director.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. A one-time extension of up to two years may be added to this review cycle. Status of the publication can be ascertained from the API Standards Department, telephone (202) 682-8000. A catalog of API publications and materials is published annually by API, 1220 L Street, NW, Washington, DC 20005.

Suggested revisions are invited and should be submitted to the Standards Department, API, 1220 L Street, NW, Washington, DC 20005, [standards@api.org](mailto:standards@api.org).

# Contents

Page

<b>1</b>	<b>Scope</b>	<b>1</b>
<b>2</b>	<b>Normative References</b>	<b>1</b>
<b>3</b>	<b>Terms, Definitions, Acronyms, and Abbreviations</b>	<b>2</b>
<b>3.1</b>	<b>Terms and Definitions</b>	<b>2</b>
<b>3.2</b>	<b>Acronyms and Abbreviations</b>	<b>5</b>
<b>4</b>	<b>Specifications</b>	<b>8</b>
<b>4.1</b>	<b>Equipment</b>	<b>8</b>
<b>4.2</b>	<b>Materials</b>	<b>8</b>
<b>5</b>	<b>Qualification of Welding Procedures with Filler Metal Additions</b>	<b>9</b>
<b>5.1</b>	<b>Procedure Qualification</b>	<b>9</b>
<b>5.2</b>	<b>Record</b>	<b>9</b>
<b>5.3</b>	<b>Welding Procedure Specification</b>	<b>9</b>
<b>5.4</b>	<b>Essential Variables</b>	<b>13</b>
<b>5.5</b>	<b>Welding of Test Joints—Butt Welds</b>	<b>17</b>
<b>5.6</b>	<b>Testing of Welded Joints—Butt Welds</b>	<b>17</b>
<b>5.7</b>	<b>Welding of Test Joints—Fillet Welds</b>	<b>23</b>
<b>5.8</b>	<b>Testing of Welded Joints—Fillet Welds</b>	<b>24</b>
<b>6</b>	<b>Qualification of Welders</b>	<b>26</b>
<b>6.1</b>	<b>General</b>	<b>26</b>
<b>6.2</b>	<b>Single Qualification</b>	<b>26</b>
<b>6.3</b>	<b>Multiple Qualification</b>	<b>27</b>
<b>6.4</b>	<b>Visual Examination</b>	<b>29</b>
<b>6.5</b>	<b>Destructive Testing</b>	<b>29</b>
<b>6.6</b>	<b>Nondestructive Testing (NDT)—Butt Welds Only</b>	<b>31</b>
<b>6.7</b>	<b>Retesting</b>	<b>31</b>
<b>6.8</b>	<b>Records</b>	<b>31</b>
<b>7</b>	<b>Design and Preparation of a Joint for Production Welding</b>	<b>31</b>
<b>7.1</b>	<b>General</b>	<b>31</b>
<b>7.2</b>	<b>Alignment</b>	<b>32</b>
<b>7.3</b>	<b>Use of Lineup Clamp for Butt Welds</b>	<b>32</b>
<b>7.4</b>	<b>Bevel</b>	<b>32</b>
<b>7.5</b>	<b>Weather Conditions</b>	<b>32</b>
<b>7.6</b>	<b>Clearance</b>	<b>32</b>
<b>7.7</b>	<b>Cleaning Between Beads</b>	<b>32</b>
<b>7.8</b>	<b>Position Welding</b>	<b>33</b>
<b>7.9</b>	<b>Roll Welding</b>	<b>33</b>
<b>7.10</b>	<b>Identification of Welds</b>	<b>33</b>
<b>7.11</b>	<b>Preheat and PWHT</b>	<b>33</b>
<b>8</b>	<b>Inspection and Testing of Production Welds</b>	<b>33</b>
<b>8.1</b>	<b>Rights of Inspection</b>	<b>33</b>
<b>8.2</b>	<b>Methods of Inspection</b>	<b>33</b>
<b>8.3</b>	<b>Qualification of Inspection Personnel</b>	<b>34</b>

## Contents

	Page
8.4 Certification of NDT Personnel .....	34
9 Acceptance Standards for NDT .....	35
9.1 General .....	35
9.2 Rights of Rejection .....	35
9.3 Radiographic Testing .....	35
9.4 Magnetic Particle Testing .....	42
9.5 Liquid Penetrant Testing .....	43
9.6 Ultrasonic Testing .....	44
9.7 Visual Acceptance Standards for Undercutting .....	46
10 Repair and Removal of Weld Defects .....	46
10.1 General .....	46
10.2 Authorization for Repair .....	46
10.3 Repair Procedure .....	48
10.4 Repair Welder Qualification .....	53
10.5 Supervision .....	55
10.6 Acceptance Criteria .....	55
11 Procedures for NDT .....	55
11.1 Radiographic Test Methods .....	55
11.2 Magnetic Particle Test Method .....	61
11.3 Liquid Penetrant Test Method .....	61
11.4 Ultrasonic Test Methods .....	61
12 Mechanized Welding with Filler Metal Additions .....	66
12.1 Acceptable Processes .....	66
12.2 Procedure Qualification .....	66
12.3 Record .....	67
12.4 Welding Procedure Specification .....	67
12.5 Essential Variables .....	69
12.6 Qualification of Welding Equipment and Operators .....	71
12.7 Records of Qualified Operators .....	72
12.8 Inspection and Testing of Production Welds .....	72
12.9 Acceptance Standards for NDT .....	72
12.10 Repair and Removal of Defects .....	72
12.11 Radiographic Testing .....	72
12.12 Ultrasonic Testing .....	72
13 Automatic Welding Without Filler Metal Additions .....	72
13.1 Acceptable Processes .....	72
13.2 Procedure Qualification .....	72
13.3 Record .....	75
13.4 Welding Procedure Specification .....	76
13.5 Essential Variables .....	77
13.6 Qualification of Equipment and Operators .....	78
13.7 Records of Qualified Operators .....	78
13.8 Quality Assurance of Production Welds .....	78

## Contents

	Page
<b>13.9 Acceptance Standards for NDT</b> .....	79
<b>13.10 Repair and Removal of Defects</b> .....	79
<b>13.11 Radiographic Procedure</b> .....	79
<b>Annex A (normative) Alternative Acceptance Standards for Girth Welds</b> .....	80
<b>Annex B (normative) In-service Welding</b> .....	102
<b>Annex C (normative) Requests for Interpretation and Request for Revision to the Document</b> .....	117
<b>Figures</b>	
<b>1 Sample Welding Procedure Specification Form</b> .....	10
<b>2 Sample Coupon Test Report</b> .....	11
<b>3 Location of Test Butt Weld Specimens for Procedure Qualification Test</b> .....	18
<b>4 Tension Test Specimen</b> .....	20
<b>5 Nick Break Test Specimen</b> .....	21
<b>6 Dimensioning of Imperfections in Exposed Weld Surfaces</b> .....	22
<b>7 Root and Face Bend Test Specimen: Wall Thicknesses Less Than or Equal to 0.500 in. (12.7 mm)</b> ...	22
<b>8 Jig for Guided-bend Tests</b> .....	23
<b>9 Side Bend Test Specimen: Wall Thicknesses Greater than 0.500 in. (12.7 mm)</b> .....	24
<b>10 Location of Nick Break Test Specimens: Fillet Weld Procedure and Welder Qualification Test Welds</b> .....	25
<b>11 Location of Nick Break Test Specimens: Fillet Weld Procedure and Welder Qualification Test Welds, Including Size-to-size Branch Connection Welder Qualification Test</b> .....	25
<b>12 Location of Test Butt Weld Specimens for Welder Qualification Test</b> .....	28
<b>13 Inadequate Penetration Without High-low</b> .....	35
<b>14 Inadequate Penetration Due to High-low</b> .....	36
<b>15 Inadequate Cross Penetration</b> .....	36
<b>16 Incomplete Fusion at Root of Bead or Top of Joint</b> .....	36
<b>17 Incomplete Fusion Due to Cold Lap</b> .....	37
<b>18 Internal Concavity</b> .....	37
<b>19 Maximum Distribution of Gas Pockets: Wall Thickness (<i>t</i>) Less Than or Equal to 0.500 in. (12.7 mm)</b> .....	40
<b>20 Maximum Distribution of Gas Pockets: Wall Thickness (<i>t</i>) Greater Than 0.500 in. (12.7 mm)</b> .....	41
<b>21 Hardness Locations for Full Thickness Repair Procedure Qualification</b> .....	51
<b>22 Hardness Locations for Partial Thickness Repair Procedure Qualification at Weld Centerline</b> .....	51
<b>23 Hardness Locations for Cover Pass Repair Procedure at Weld Centerline</b> .....	52
<b>24 Hardness Location for Back Weld Repair or Internal Partial Thickness Repair Procedure at Weld Centerline</b> .....	52
<b>25 Hardness Locations for Cover Pass Repair Procedure at Fusion Line</b> .....	53
<b>26 Hardness Locations for Partial Thickness Repair at Fusion Line</b> .....	53
<b>27 Reference Block for Manual Ultrasonic Testing</b> .....	64
<b>28 Establishing Distance, Refracted Angle, and Velocity</b> .....	64
<b>29 Transfer Procedure</b> .....	65
<b>30 Location of Test Butt Weld Specimens for Flash Weld Procedure Qualification Test: Outside Diameter Greater Than 18 in. (457 mm) but Less Than or Equal to 24 in. (610 mm)</b> .....	73
<b>31 Location of Test Butt Weld Specimens for Flash Weld Procedure Qualification Test: Outside Diameter Greater Than 24 in. (610 mm) but Less Than or Equal to 30 in. (762 mm)</b> .....	74
<b>32 Location of Test Butt Weld Specimens for Flash Weld Procedure Qualification Test: Outside Diameter Greater Than 30 in. (762 mm)</b> .....	74

## Contents

Page

33	Two-in. Nick Break Test Specimen	76
A.1	Top View (Width in Circumferential Direction) of the Tensile Test Specimen	86
A.2	Charpy Specimen and V-notch Location for the HAZ Impact Testing.	87
A.3	Orientation of CTOD Test Specimen	88
A.4	Machining Objective for CTOD Test Specimen with Respect to Pipe Wall.	88
A.5	Location of Notch for Weld Metal Specimen	89
A.6	Location of Notch for Heat-affected Zone Specimen	89
A.7	Option 1 Imperfection Limits for $CTOD \geq 0.010$ in. (0.25 mm)	91
A.8	Option 1 Imperfection Limits for $0.004$ in. (0.10 mm) $\leq CTOD < 0.010$ in. (0.25 mm)	92
A.9	Allowable Imperfection Size Curves Before and After Height Adjustment	94
A.10	Schematic Overview of the Option 2 Procedure	95
A.11	Criteria for Evaluation of Imperfection Interaction	101
B.1	Examples of Typical Temper Bead Deposition Sequences	103
B.2	Suggested Procedure and Welder Qualification Test Assembly	105
B.3	Suggested Location of Test Specimens for Sleeve and Branch Welds	107
B.4	Suggested Location of Test Specimens for Weld Deposition Repair	108
B.5	Macro Test Specimen—In-service Welds	109
B.6	Face Bend Test Specimen	110
B.7	Reinforcing Pad	112
B.8	Reinforcing Saddle	113
B.9	Encirclement Sleeve	113
B.10	Encirclement Tee	114
B.11	Encirclement Sleeve and Saddle	114
B.12	Encirclement Saddle	115

### Tables

1	Filler Metal Groups	15
2	Type and Number of Test Specimens for Procedure Qualification Test	19
3	Type and Number of Butt Weld Test Specimens per Welder for Welder Qualification Test and Destructive Testing of Production Welds	30
4	Maximum Dimensions of Undercutting	46
5	Type and Number of Butt Weld Test Specimens per Repair Type for Repair Procedure Qualification	49
6	Repair Weld Maximum Hardness Values, HV10	54
7	Type and Number of Butt Weld Test Specimens per Repair Type for Repair Welder Qualification	54
8	Weld Thickness vs Diameter of ASTM E747 Wire Type IQI	58
9	Weld Thickness vs Diameter of ISO Wire Type IQI	59
10	Type and Number of Test Specimens for Procedure Qualification Test (Flash Weld Only)	75
A.1	Allowed Range of Variation from the Targeted Mean Values for a Lot Defined by Controlled Chemical Composition	84
A.2	Initial Allowable Imperfection Size for $P_f = 0.825$	93
A.3	Example Acceptance Table	94
A.4	Acceptance Limits for Buried Volumetric Imperfections	99
A.5	Acceptable Limits for Unrepaired Arc Burns	100
B.1	Type and Number of Specimens—In-service Welding Procedure Qualification Test	109
B.2	Type and Number of Test Specimens for Longitudinal Seam Welds—Welder Qualification Test	111

# Welding of Pipelines and Related Facilities

## 1 Scope

This standard covers the gas and arc welding of butt, fillet, and socket welds in carbon and low-alloy steel piping used in the compression, pumping, and transmission of crude petroleum, petroleum products, fuel gases, carbon dioxide, nitrogen, and where applicable, covers welding on distribution systems. It applies to both new construction and in-service welding. The welding may be done by a shielded metal arc welding, submerged arc welding, gas tungsten arc welding, gas metal arc welding, flux-cored arc welding, plasma arc welding, oxyacetylene welding, or flash butt-welding process or by a combination of these processes using a manual, semiautomatic, mechanized, or automatic welding technique or a combination of these techniques. The welds may be produced by position or roll welding or by a combination of position and roll welding.

This standard also covers the procedures for radiographic, magnetic particle, liquid penetrant, and ultrasonic testing, as well as the acceptance standards to be applied to production welds tested to destruction or inspected by radiographic, magnetic particle, liquid penetrant, ultrasonic, and visual testing methods.

The values stated in either U.S. customary units (USC) units or metric units (SI) are to be regarded separately as standard. Each system is to be used independently of the other, without combining values in any way.

The figures depicted in this standard are not drawn to scale.

It is intended that all work performed in accordance with this standard meets or exceeds the requirements of this standard.

While this standard is comprehensive, it may not address all issues that may arise. The absence of guidance or requirements is not to be considered prohibitive to a particular activity or approach that is based upon sound engineering judgment. For example, other industry standards, reliable engineering tests and analyses, or established industry practices may provide useful reference to establish sound engineering judgment.

## 2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 5L, *Specification for Line Pipe*

API Recommended Practice 2201, *Safe Hot Tapping Practices in the Petroleum and Petrochemical Industries*

ASNT ACCP <sup>1</sup>, *ASNT Central Certification Program*

ASNT SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

ASTM A370 <sup>2</sup>, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

<sup>1</sup> American Society for Nondestructive Testing, 1711 Arlingate Lane, P.O. Box 28518, Columbus, Ohio 43228, [www.asnt.org](http://www.asnt.org).

<sup>2</sup> ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, [www.astm.org](http://www.astm.org).