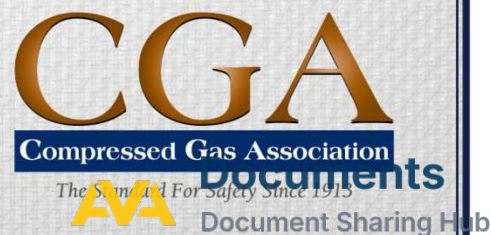


This document licensed for the sole use of the purchaser. It may not be shared with any other person or used after the expiration date without the express written permission of the CGA. Any unauthorized use, reproduction, distribution, or modification of this printed page will result in a \$5,000 liquidated damages fee plus loss of access to CGA publications for one year for your company.

CGA C-3—2019

**STANDARD FOR WELDING ON
THIN-WALLED STEEL CYLINDERS**

EIGHTH EDITION



PLEASE NOTE:

The information contained in this document was obtained from sources believed to be reliable and is based on technical information and experience currently available from members of the Compressed Gas Association, Inc. and others. However, the Association or its members, jointly or severally, make no guarantee of the results and assume no liability or responsibility in connection with the information or suggestions herein contained. Moreover, it should not be assumed that every acceptable commodity grade, test or safety procedure or method, precaution, equipment or device is contained within, or that abnormal or unusual circumstances may not warrant or suggest further requirements or additional procedure.

This document is subject to periodic review, and users are cautioned to obtain the latest edition. The Association invites comments and suggestions for consideration. In connection with such review, any such comments or suggestions will be fully reviewed by the Association after giving the party, upon request, a reasonable opportunity to be heard. Proposed changes may be submitted via the Internet at our website, www.cganet.com.

This document should not be confused with federal, state, provincial, or municipal specifications or regulations; insurance requirements; or national safety codes. While the Association recommends reference to or use of this document by government agencies and others, this document is purely voluntary and not binding unless adopted by reference in regulations.

A listing of all publications, audiovisual programs, safety and technical bulletins, and safety posters is available via the Internet at our website at www.cganet.com. For more information contact CGA at Phone: 703-788-2700, ext. 799. E-mail: customerservice@cganet.com.

Work Item 17-008
Cylinder Specifications Committee

NOTE—Technical changes from the previous edition are underlined.

NOTE—Appendix D (Normative) is a requirement.

NOTE—Appendices A, B, C, and E (Informative) are for information only.

EIGHTH EDITION: 2019
SEVENTH EDITION: 2005
SIXTH EDITION: 2003
FIFTH EDITION: 2000

© 2019 The Compressed Gas Association, Inc. All rights reserved.

All materials contained in this work are protected by United States and international copyright laws. No part of this work may be reproduced or transmitted in any form or by any means, electronic or mechanical including photocopying, recording, or any information storage and retrieval system without permission in writing from The Compressed Gas Association, Inc. All requests for permission to reproduce material from this work should be directed to The Compressed Gas Association, Inc., 14501 George Carter Way, Suite 103, Chantilly VA 20151. You may not alter or remove any trademark, copyright or other notice from this work.

This document licensed for the sole use of the purchaser. It may not be shared with any other person or used after the expiration date without the express written permission of the CGA. Any unauthorized use, reproduction, distribution, or modification of this printed page will result in a \$5,000 liquidated damages fee plus loss of access to CGA publications for one year for your company.

Contents	Page
1 Introduction.....	1
2 Scope	1
2.1 Procedure qualification	1
2.2 Operator qualification	1
2.3 Container production acceptance.....	1
2.4 Radiographic inspection	1
3 Definitions.....	1
4 Procedure qualification	2
4.1 Applicability.....	2
4.2 Procedure specification	2
4.3 Welding procedures.....	2
4.4 Base material.....	2
4.5 Positions of welds.....	2
4.6 Type, number, and method of preparation of test specimens	3
4.7 Methods of testing specimens and required test results	3
4.8 Records	3
4.9 Essential variables	3
5 Operator qualification	5
5.1 Applicability.....	5
5.2 Welding procedures.....	5
5.3 Base material.....	5
5.4 Positions of welds.....	5
5.5 Type, number, and method of preparation of test specimens	5
5.6 Methods of testing specimens and acceptable test results	6
5.7 Retests	6
5.8 Period of effectiveness	6
5.9 Records	7
5.10 Essential variables	7
6 Container production acceptance.....	7
6.1 Location of details for required tests.....	7
6.2 Production lots.....	7
6.3 Radiographic examination	7
7 Radiographic inspection	7
7.1 Applicability.....	7
7.2 Technician qualifications	8
7.3 Preparation	8
7.4 Terminology.....	8
7.5 Darkroom facilities	8
7.6 Film viewing facilities.....	8
7.7 Film processing	9
7.8 Penetrameters	9
7.9 Film identification and inspection data.....	10
7.10 Selection of technique	11
7.11 Limits of acceptability	11
7.12 Retests	12
7.13 Retention of radiographs	12
8 Container repair—applicability	12

9	Test methods.....	12
9.1	Positions of welds.....	12
9.2	Tension test (transverse to weld)	13
9.3	Flattening test (on cylindrical section)	14
9.4	Flattening test (on sphere).....	15
9.5	Root-break test.....	15
9.6	Macro-etch test.....	16
9.7	Guided-bend test.....	16
10	Assignment of electrodes	20
11	References	21

Tables

Table 1—Composition limits for material groupings.....	3
Table 2—Procedure qualification test specimens	4
Table 3—Operator qualification test specimens	6
Table 4—Assignment of electrodes and welding rods for procedures and operator qualification	21

Figures

Figure 1—Example of a penetrometer	9
Figure 2—Suggested format for radiograph documentation	10
Figure 3—Position of welds	13
Figure 4—Specimen for tension test.....	14
Figure 5—Specimen for guided-bend test	17
Figure 6—Standard guided-bend test jig	18
Figure 7—Alternate guided-bend test jig.....	19
Figure 8—Illustrated methods for alternate guided-bend test	20

Appendices

Appendix A—Recommended form for procedure qualification record (Informative).....	22
Appendix B—Recommended form of welding procedure specification (Informative)	23
Appendix C—Recommended form for manufacturer's record of welder or welding operator qualification tests (Informative)	24
Appendix D—Dimensional tolerances (Normative).....	25
Appendix E—Typical weld joints (Informative).....	26

1 Introduction

The Compressed Gas Association, Inc. (CGA) has established this standard to promote uniformity and serviceability of compressed gas containers produced under the specifications of the U.S. Department of Transportation (DOT) and Transport Canada (TC) for the manufacturers of welded steel compressed gas containers and for the inspectors who may be called upon to qualify welding on such containers. Establishment of standards for procedure and operator qualification and for radiographic inspection was necessary to define parameters concerning the gauge of materials, i.e., thickness, used in compressed gas containers with a maximum service pressure of 900 psi (62.1 bar).^{1, 2}

2 Scope

This publication addresses specific production welding techniques and is not intended to cover all welding. When evaluating techniques other than those covered in detail in this publication, refer to ASME *Boiler and Pressure Vessel Code*, Section IX, "Welding and Brazing Qualifications," for more information [2]. This ASME Code applies to essential variables and material types.

This standard is applicable to DOT/TC specification containers of 900 psi (62.1 bar) maximum service pressure, 454 kg (1000 lb) maximum water capacity, and maximum wall thickness of 0.375 in (9.53 mm). This standard includes the following subjects.

2.1 Procedure qualification

Requirements relating to welding procedure require that each procedure be qualified by tests to demonstrate that soundness, strength, and ductility of joints are obtainable under the welding conditions specified.

2.2 Operator qualification

Requirements relating to the welding operator require that each operator be qualified by tests that adhere to an approved welding procedure to demonstrate that the operator possesses a welding ability meeting the requirements of the approved procedure.

2.3 Container production acceptance

Requirements relating to the use of sampling tests apply to qualifying production lots for acceptance by the certifying inspector.

2.4 Radiographic inspection

Requirements relating to radiographic inspection that apply to details of radiographic inspection techniques conforming to currently recognized industrial practices not found in container specifications.

3 Definitions

For the purpose of this publication, the following definitions apply.

3.1 Publication terminology

3.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

¹ bar shall indicate gauge pressure unless otherwise noted as (bar, abs) for absolute pressure or (bar, differential) for differential pressure. All bar values are rounded off per [CGA P-11, Metric Practice Guide for the Compressed Gas Industry](#) [1].

² References are shown by bracketed numbers and are listed in order of appearance in the reference section.

3.1.2 Should

Indicates that a procedure is recommended.

3.1.3 May

Indicates that the procedure is optional.

3.1.4 Will

Is used only to indicate the future, not a degree of requirement.

3.1.5 Can

Indicates a possibility or ability.

4 Procedure qualification**4.1 Applicability**

Procedures for welding of pressure parts and attachments to pressure parts of compressed gas containers shall be qualified in accordance with this standard.

4.2 Procedure specification

The procedures of welding to be followed in construction shall be established and recorded by the manufacturer as a procedure specification. Recommended forms for these procedures are given in Appendix A and Appendix B. It is not necessary that these exact forms be used, but the information contained therein shall be included in any alternate form used.

If any changes are made in a procedure, the procedure specification shall be revised or amended to show the changes. If certain changes are made in a procedure specification, requalification of the revised procedure shall be required as stated in 4.9.

4.3 Welding procedures

Welding procedures on specimens prepared for qualification tests shall comply with the welding procedure specification. For qualification of a manual welding process, the container or test plate shall be manually welded. For qualification of an automatic welding process, the container or test plate shall be welded by the production procedure using identical equipment in production with respect to position of work; protection of hot metal; and automatic control of preheat, feed, speed, current, oscillation, interruption, rate of cooling, etc. Qualification of automatic welding on one type of equipment shall not qualify the process on another type of equipment that lacks any single element of control provided on the first.

4.4 Base material

Base materials for welding of qualification test specimens shall be of the same alloy group as the production materials. The grouping of materials for procedure qualification shown in Table 1 is made on the basis of hardenability characteristics. Base materials of different analysis within a group may be indiscriminately substituted for a material that was used in the qualification test.

The test material to be used for qualification of girth welds shall be formed to the smallest container diameter that is to be qualified. This also qualifies all larger diameters. Diameter is not a consideration for longitudinal or attachment welds. The thickness of the test material shall be within –20% and +50% of the material to be qualified.

The qualification test material shall be in the same heat-treated condition before testing as the production material to be welded. If the production material is to be heat treated after welding, the qualification test material shall be given the same heat treatment before physical tests are conducted.

4.5 Positions of welds

The positions of welds used in welding of qualification test specimens and production containers shall be restricted to flat and horizontal positions in accordance with welding positions, which are shown in Section 9.

Table 1—Composition limits for material groupings

Group	Alloy family	C	Mn	P	S	Si	Cr	Ni	Mo	Cb	Cu	Ti
I	Carbon steels	0.25	1.00	0.045	0.05	0.50				0.04		
II	Carbon-manganese steel	0.25	1.00/ 1.65	0.04	0.05	0.50				0.04	0.40	
III	Alloy steels	0.25/ 0.35	0.40/ 0.90	0.04	0.05	0.20/ 0.35	0.80/ 1.10		0.15/ 0.25			
IV	Austenitic stainless steels	0.08	2.00	0.045	0.03	1.00	16.0/ 20.0	8.0/ 14.0	2.0/ 3.0	10x % C min 1.0% max		5x % C min 0.6% max
NOTES 1 Chemical analysis limits are given in percent. All single value entries are maximums. 2 Addition of unspecified elements to obtain alloying <u>effects</u> is permitted <u>and it shall be reported</u>. 3 These specific chemical compositions are found in Title 49 of the U.S. <i>Code of Federal Regulations</i> (49 CFR) Part 178 and CSA B339, <i>Cylinders, spheres, and tubes for the transportation of dangerous goods</i> [3, 4].												

4.6 Type, number, and method of preparation of test specimens

4.6.1 Type

Each type of welded joint in a container shall be tested for each procedure to be qualified.

4.6.2 Number

Test specimens shall be taken for each type of joint as specified in Table 2.

NOTE—Cylinders can contain heads that are convex to pressure. These cylinders can contain a joggle butt or lap joint with a fillet weld. In turn, there could be insufficient material to conduct a guided-bend, face-bend, or tensile test. In this case, a macro-etch of the weld is an acceptable practice that would meet the criteria of Table 2.

4.6.3 Method of preparation

The number of test specimens and method of preparation of specimens shall be in accordance with applicable references in Table 2.

4.7 Methods of testing specimens and required test results

Methods of testing specimens and required test results shall be in accordance with applicable references in Table 2.

4.8 Records

Records of test results shall be kept by the manufacturer and shall be made available to those authorized to examine them. Recommended forms for recording the results of both the procedure qualification and operator qualification tests are in Appendix A and Appendix C.

4.9 Essential variables

The welding procedure shall be set up as a new procedure specification and shall be completely requalified when any of the following changes are made in the procedure:

- Change in the specification of either or both of the base metals to be welded from one group number to another group number as shown in Table 1;
- Change in filler metal;

- Change in the nominal composition or type of flux used in submerged arc welding. A change in flux particle size does not require requalification;
- Addition of welding positions other than those already qualified;
- Decrease of 50 °F (28 °C) or more in the minimum specified preheating temperature;
- Omission or addition of a backing strip in single-welded butt joints;
- Change from multiple pass per side to single pass per side;
- Change from single arc to multiple arc, or vice versa; or
- Change from one type of shielding gas to another or a change in the gas composition of 15% or greater.

NOTE—Changes other than those given may be made in a procedure without the necessity for requalification provided the procedure specification is revised to show such changes.

Table 2—Procedure qualification test specimens

Type of joint	Type of test required	Purpose of test	Number of specimens	Method of preparation testing and required test results
Longitudinal groove welded butt	Tension (transverse to weld)	Strength	2	See 9.2
	Guided-bend root-bend	Soundness	2	See 9.7
	Guided-bend face-bend	Soundness	2	See 9.7
Butt weld of seam in sphere	Companion bar reduced section tension (transverse to weld)	Strength	2	See 9.2
	Flattening ¹⁾	Ductility	1	See 9.4
	Guided-bend root-bend ²⁾	Soundness	2	See 9.7
	Guided-bend face-bend ²⁾	Soundness	2	See 9.7
Circumferential welded butt	Flattening ¹⁾	Ductility	2	See 9.3
	Guided-bend root-bend ²⁾	Soundness	2	See 9.7
	Guided-bend face-bend ²⁾	Soundness	2	See 9.7
Circumferential welded lap or joggle butt	Flattening ¹⁾	Ductility	2	See 9.3
	Guided-bend root-bend ²⁾	Soundness	2	See 9.7
Welded attachments on pressure parts	Root-break ³⁾	Soundness	2	See 9.5
Fillet for attachment of bosses, pads, or heads	Macro-etch	Soundness	2	See 9.6
NOTES 1 For the order of removal of test specimens on circumferential seams, each pair of test specimens shall be taken 180 degrees apart. On longitudinal seams, each pair of test specimens shall be taken not less than 50% of the seam length apart. 2 For drawings of typical weld joints, see Appendix E. ¹⁾ Performed only if the cylinder specification requires a flattening test. ²⁾ A root-break test or radiographic inspection of the full qualification test weld length may be substituted at the manufacturer's option. ³⁾ If root-break specimens will not fracture in the joint, macro-etch tests may be substituted.				

5 Operator qualification

5.1 Applicability

Welding of pressure parts and attachments to other pressure parts shall be performed by an operator qualified in accordance with these standards for each procedure to be used in production.

If certain changes are made in a procedure specification, requalification of the operator shall be required as outlined in 5.10.

A welding machine operator is any individual who makes a mechanical or electrical adjustment on the welding machine that affects the quality of the resultant weldment. Persons attending totally automatic welding processors do not need to be qualified under this requirement.

5.2 Welding procedures

Approval of the welding procedure qualification and welding operator qualification tests shall be by any of the following three methods:

- DOT authorized independent inspector for DOT cylinders;
- TC registered independent inspector for TC cylinders; or
- Manufacturer applies an ISO 9000 or nationally recognized quality system that produces internal audits to ensure requirements of 5.8 and 5.9 are met.

The operator welding specimens prepared for qualification tests shall comply with the welding procedure specification.

Operators who weld acceptable qualification test specimens are also qualified for that welding procedure.

5.3 Base material

Base materials for welding of qualification test specimens shall be of the same alloy group as the production materials. Refer to Table 1. The material to be used for qualification of girth welds shall be formed to the smallest container diameter that is to be qualified. This will also qualify all larger diameters. Diameter is not a consideration for longitudinal or attachment welds. The thickness of the material shall be within –20% and +50% of the material to be qualified.

The qualification test material shall be in the same heat-treated condition prior to test as the production material to be welded. If the production material is to be heat treated after welding, the qualification test material shall be given the same heat treatment before physical tests are conducted.

5.4 Positions of welds

The positions of welds for operator qualification shall be the same as those to be used by the operator in production.

5.5 Type, number, and method of preparation of test specimens

The operator shall be tested on each type of welded joint that they will weld in production. The types of required tests and the number of test specimens that shall be taken for each type of welded joint for which the operator is to be qualified are as specified in Table 3.

NOTE—Cylinders can contain heads that are convex to pressure. These cylinders can contain a joggle butt or lap joint with a fillet weld. In turn, there might not be sufficient material to conduct a guided-bend or face-bend test. In this case, a macro-etch of the weld is an acceptable practice for meeting the criteria of Table 3.

Alternatively, welded joints for which the operator is to be qualified may be radiographically inspected and shall satisfy the acceptability requirements of 7.10. The inspected joint shall have a length of at least 3 ft (914 mm).

For girth welds on small diameter containers when weld length is less than 3 ft (914 mm), two containers shall be welded and radiographically inspected to satisfy requirements.

Table 3—Operator qualification test specimens

Type of joint	Type of test required	Purpose of test	Number of specimens	Method of preparation, testing, and required test results
Longitudinal groove welded butt	Guided-bend root-bend ¹⁾	Soundness	2	See 9.7
	Guided-bend face-bend ¹⁾	Soundness	2	See 9.7
Butt weld of seam in sphere	Guided-bend root-bend ¹⁾	Soundness	2	See 9.7
	Guided-bend face-bend ¹⁾	Soundness	2	See 9.7
Circumferential welded butt	Guided-bend root-bend ¹⁾	Soundness	2	See 9.7
	Guided-bend face-bend ¹⁾	Soundness	2	See 9.7
Circumferential welded lap or joggle butt	Guided-bend root-bend ¹⁾	Soundness	2	See 9.7
Welded attachments on pressure parts	Root-break ²⁾	Soundness	2	See 9.5
Fillet for attachment of bosses, pads, or heads	Macro-etch	Soundness	2	See 9.6
NOTES 1 For the method of removal of test specimens on circumferential seams, each pair of test specimens shall be taken 180 degrees apart. On longitudinal seams, each pair of test specimens shall be taken not less than 50% of the seam length apart. 2 For drawings of typical weld joints, see Appendix E. ¹⁾ A root-break test or radiographic inspection of the full qualification test weld length may be substituted at the option of the manufacturer. ²⁾ If root-break specimens will not fracture in the joint, macro-etch tests may be substituted.				

5.6 Methods of testing specimens and acceptable test results

Methods of testing specimens and acceptable test results shall be in accordance with the applicable reference in Table 3 and shall meet all the requirements specified for such welds.

5.7 Retests

Where an operator fails to meet the requirements of one test weld, a retest may be allowed under either of the following conditions:

- the retest is performed immediately and consists of two welds of each type the operator failed, both welds shall meet all requirements for such welds; or
- there is evidence that the operator has had further training or practice.

5.8 Period of effectiveness

The operator qualification tests specified herein shall remain in effect unless the welder or welding operator has not welded with a given fusion welding process for a period of 3 months. This period may be extended to 6 months if the welder has welded with another process. In addition, the operator qualification tests specified herein shall remain in effect unless there is a specific reason to question the ability of the welder or welding operator to meet the requirements for qualification in a given process.