

Procedures for Testing Casing and Tubing Connections

API RECOMMENDED PRACTICE 5C5
FOURTH EDITION, JANUARY 2017

ADDENDUM 1, MAY 2021



American
Petroleum
Institute

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. The use of API publications is voluntary. In some cases, third parties or authorities having jurisdiction may choose to incorporate API standards by reference and may mandate compliance.

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.

Copyright © 2017 American Petroleum Institute. 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, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

Foreword

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.

The verbal forms used to express the provisions in this document are as follows.

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

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

May: As used in a standard, “may” denotes a course of action permissible within the limits of a standard.

Can: As used in a standard, “can” denotes a statement of possibility or capability.

Informative elements: As used in a standard, “informative” denotes elements that identify the document; introduce its content and explain its background, development, and relationship with other documents; or provide additional information intended to assist the understanding or use of the document.

Normative elements: As used in a standard, “normative” denotes elements that describe the scope of the document and that set out provisions that are required to implement the standard.

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, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001. 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, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001.

Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

	Page
1 Scope	1
2 Normative References	1
3 Terms, Definitions, Symbols, and Abbreviations	1
3.1 Terms and Definitions	1
3.2 Abbreviations	5
3.3 Symbols	6
4 General Requirements	9
4.1 General Information	9
4.2 Connection Testing Flow Chart	9
4.3 Connection Specification Sheet and Test Specimen Datasheet	12
4.4 Quality Control	13
4.5 Test Facility Safety	13
5 General Test Requirements	14
5.1 Test Principle	14
5.2 Test Matrix	16
5.3 Test Program	21
5.4 Calibration and Accreditation Requirements	22
5.5 Material Characterization	23
5.6 Makeup and Breakout Procedures	27
5.7 Internal Pressure Leak Detection for TS-B and TS-C Setup	29
5.8 Leak Detection for TS-A Setup	36
5.9 Data Acquisition and Test Methods	40
5.10 Elevated Temperature Tests	45
6 Test Specimen Preparation	46
6.1 General Test Objectives	46
6.2 Test Specimen Identification and Marking	48
6.3 Test Specimen Preparation	48
6.4 Test Specimen Machining	50
6.5 Machining Tolerances	50
6.6 Grooved Torque Shoulder	52
7 Test Procedures	52
7.1 Principle	52
7.2 Makeup/Breakout Tests	53
7.3 Test Load Envelope Tests	55
7.4 Limit Load Tests	88
7.5 Limit Load Test Path	91
8 Acceptance Criteria	92
8.1 General	92
8.2 Makeup and Breakout Tests	92
8.3 Test Load Envelope Tests	93
8.4 Limit Load Tests	95
9 Test Report	95

Contents

	Page
Annex A (normative) Connection Specification Sheet and Test Specimen Datasheet	96
Annex B (normative) Data Forms	99
Annex C (normative) Connection Full Test Report	108
Annex D (informative) Calculations for Pipe Body Reference Envelope and Examples of Load Schedules for Each Test Series	113
Annex E (informative) Frame Load Range Determination	182
Annex F (informative) Product Line Validation	184
Annex G (informative) Special Application Testing	192
Bibliography	198
Figures	
1 Flow Chart for Determining Input Parameters Used to Construct Pipe Body Reference Envelope for a Test Specimen	10
2 Flow Chart for Determining Ambient and Elevated Temperature Pipe Body Reference Envelope and Connection Evaluation Envelope for a Test Specimen	11
3 Flow Chart for Determining Ambient and Elevated Temperature Test Load Envelopes and Test Load Schedules for a Test Specimen	12
4 CAL I Test Requirements and Sequence	17
5 CAL II Test Requirements and Sequence	18
6 CAL III Test Requirements and Sequence	19
7 CAL IV Test Requirements and Sequence	20
8 Collared Leak Trap Device for Internal Pressure Leak Detection	31
9 Flexible Boot Leak Trap Device for Internal Pressure Leak Detection	31
10 Ported Box Leak Trap Device for Internal Pressure Leak Detection	32
11 Example Configuration of Internal Pressure Leak Detection by Bubble Method	33
12 Example of a Plot for Determining Leak Detection Sensitivity	34
13 Example Configuration of Leak Detection by Helium Mass Spectrometer Method	35
14 Example Setup for TS-A	38
15 Example of Leak Detection System for TS-A with External Pressure Chamber on Specimen for Ambient Internal and External Pressure Testing	39
16 Example Setup for Elevated TS-A (Internal Pressure)	41
17 Example Setup for Elevated TS-A (External Pressure)	41
18 Test Specimen Nomenclature and Unsupported Length	49
19 Schematic Description of Test Specimen Interference Ranges	52
20 Torque Shoulder Pressure-bypassing Grooves	53
21 Example of a Test Load Envelope Where Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same and TLE Based on 95 % of CEE for Internal Pressure and 100 % of Nominal API Collapse for External Pressure	59
22 Example of a Test Load Envelope Where Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same and TLE Based on 95 % of CEE for Internal Pressure and 95 % of Actual API Collapse for External Pressure	60
23 Example of a Test Load Envelope Where Pipe Body Reference Envelope and Connection Evaluation Envelope Are Not the Same and TLE Based on 95 % of CEE for Internal Pressure and a Combination of 100 % of Nominal API Collapse and 95 % of Actual VME for External Pressure	60

Contents

Page

24	Example of a Test Load Envelope Where the Pipe Body Reference Envelope and the Connection Evaluation Envelope Are Not the Same and TLE Based on 95 % of CEE for Internal Pressure and a Combination of 95 % of Actual API Collapse and 95 % of Actual VME for External Pressure	61
25	Example of Ambient Temperature TS-A Load Points at 95 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same, with Tension and Compression Limited to 90 % of the CEE	73
26	Example of Ambient Temperature TS-A Load Points at 95 % of the CEE for Internal Pressure and 100 % of the CEE for External Pressure Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are Not the Same, with Tension and Compression Limited to 90 % of the CEE	74
27	Example of Ambient Temperature TS-A Load Points at 90 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same.	74
28	Example of Elevated Temperature TS-A Load Points at 90 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same	75
29	Example of Ambient Temperature TS-B Load Points at 95 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same, with Tension and Compression Limited to 90 % of the CEE	83
30	Example of Ambient Temperature TS-B Load Points with Bending at 95 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same, with Tension and Compression Limited to 90 % of the CEE	83
31	Example of Ambient Temperature TS-B Load Points with Bending at 90 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same	84
32	Example of Elevated Temperature TS-B Load Points with Bending at 90 % of the CEE Where the Pipe Body Reference Envelope and Connection Evaluation Envelope Are the Same.	84
33	TS-C Thermal/Mechanical Cycles for CAL III and CAL IV	85
34	TS-C Load Path Calculation Procedure	86
35	Limit Load Test Paths (Example 1)	89
36	Limit Load Test Paths (Example 2)	90
B.1	Recommended Layout of Mother Joint and Coupling Stock Mother Tubes for Material Coupons and Full-Size Test Specimens	99
B.2	Layout for Dimensional Measurements of Test Specimens	100
B.3	Material Property Datasheet	101
B.4	Makeup/Breakout Log	102
B.5	Form for Test Specimen Pipe Geometry	103
B.6	Connection Geometry Datasheet	104
B.7	Test Log Failure/Limit Load	105
B.8	Connection Sealability Test Log (with Internal Pressure Leak Detection)	106
B.9	Connection Sealability Test Log (with External Pressure Vessel As Leak Detection)	107
D.1	Mother Joint Mapping (from Annex B)	113
D.2	Mechanical Test Requirements Flow Chart	114
D.3	Measurement Locations	116
D.4	Pipe Body Nominal VME Curve at Ambient Temperature	119
D.5	Pipe Body Nominal API Collapse Curve at Ambient Temperature	122
D.6	Pipe Body Nominal API Collapse and Proprietary High Collapse Curves at Ambient Temperature	123
D.7	Test Specimen Pipe Body Actual and Nominal VME Curves at Ambient Temperature	124
D.8	Test Specimen Pipe Body Actual and Nominal API Collapse Curves at Ambient Temperature	125
D.9	Test Specimen Pipe Body Nominal VME Curves at Ambient and Elevated Temperature	126
D.10	Test Specimen Pipe Body Nominal API Collapse Curve at Ambient and Elevated Temperature	126

Contents

Page

D.11	Test Specimen Pipe Body Proprietary High Collapse Curve at Ambient and Elevated Temperature	125
D.12	Test Specimen Pipe Body Actual VME Curves at Ambient and Elevated Temperature	126
D.13	Test Specimen Pipe Body API Actual Collapse Curve at Ambient and Elevated Temperature	128
D.14	Test Specimen CEE ^a at Ambient Temperature	130
D.15	Test Specimen CEE ^e at Elevated Temperature	131
D.16	CEE ^a Points and 80 % TLE ^a Load Points at Ambient Temperature	133
D.17	CEE ^a Points and 95 % TLE ^a Load Points at Ambient Temperature	135
D.18	CEE ^a Points and 90 % TLE ^a Load Points at Ambient Temperature	138
D.19	90 % CEE ^e Points and TLE ^e Load Points at Elevated Temperature	142
D.20	B ^a 80 % (QI, QII), TS-B Load Steps 1 to 19	145
D.21	B ^a 95 % (QI, QII, QI), TS-B Load Steps 20 to 66	146
D.22	B ^e _b 90 % (QI, QII, QI), TS-B Load Steps 67 to 155	148
D.23	B ^a _b 90 % (QI, QII, QI), TS-B Load Steps 156 to 244	152
D.24	Ten Thermal Cycles, TS-C Load Steps 1 to 44	156
D.25	Five Mechanical Cycles, TS-C Load Steps 45 to 69	158
D.26	A ^e 90 % (QI, QII), TS-A Load Steps 1 to 24	160
D.27	A ^e 90 % (QIII, QIV) and A ^e 90 % (QIV, QIII), TS-A Load Steps 25 to 51	161
D.28	A ^e 90 % (QIII, QIV) and A ^e 90 % (QIV, QIII), TS-A Load Steps 52 to 74	163
D.29	A ^e 90 % 5 QI-QIII Cycles, TS-A Load Steps 75 to 125	164
D.30	A ^a 90 % (QI, QII), TS-A Load Steps 126 to 148	167
D.31	A ^a 90 % (QIII, QIV) and A ^a 90 % (QIV, QIII), TS-A Load Steps 149 to 175	168
D.32	A ^a 90 % (QI, QII), TS-A Load Steps 176 to 198	170
D.33	A ^a 95 % (QI, QII), TS-A Load Steps 199 to 221	171
D.34	A ^a 95 % (QIII, QIV) and A ^a 95 % (QIV, QIII), TS-A Load Steps 222 to 248	173
D.35	A ^a 95 % (QI, QII), TS-A Load Steps 249 to 271	174
D.36	Test Specimen Pipe Body Reference Curves (Curves 1 ^a , 2 ^a , 4 ^a , and 5 ^a)	176
D.37	CEE ^a Points and TLE ^a Load Points	179
D.38	Test Specimen Pipe Body Reference Curves (Curves 1 ^a , 2 ^a , 4 ^a , and 5 ^a)	180
D.39	Specimen CEE ^a	181
F.1	Product Line Validation (Example 1)	187
F.2	Product Line Validation (Example 2)	189

Tables

1	Test Matrix—Sealability, Test Series and Specimen Identification Numbers	16
2	Test Specimen Objectives for CALs	47
3	Guidelines for Selecting Test Specimens for Testing a Metal-to-Metal Sealing, Tapered Thread Connection	47
4	Tolerance Limits on Machining Objectives	51
5	Thread Taper Tolerance Limits	52
6	Test Specimen Description and Summary of Test Series for a Metal-to-Metal Sealing, Tapered Thread Connection	54
7	Load Point Definitions	63
8	TS-A for CAL III and CAL IV	68
9	TS-A for CAL I and II	71
10	TS-B—CAL II, CAL III, and CAL IV	77
11	TS-B for CAL I	80
12	TS-B Additional Requirements for CAL II and CAL III (for Test Specimens that Do Not Require TS-A)	82

Contents

	Page
13 TS-C	87
A.1 Connection Specification Sheet	97
A.2 Test Specimen Datasheet	97
C.1 Reporting Format	108
D.1 Example MT Test Results from Joint 1	115
D.2 Measurements from Pup A (inches)	116
D.3 Measurements from Pup B (inches)	117
D.4 Example Pipe Parameters Used to Calculate Reference Curves at Ambient Temperature	117
D.5 Pipe Input Parameters and Pipe Parameter Descriptions for Nominal VME Curve	118
D.6 Pipe Input Parameter and Pipe Parameter Descriptions for Nominal API Collapse Curve	119
D.7 Pipe Input Parameters and Pipe Parameter Descriptions for Proprietary High Collapse Curve	122
D.8 Pipe Input Parameters and Pipe Parameter Descriptions for Actual VME Curve	123
D.9 Pipe Input Parameters and Pipe Parameter Descriptions for Actual API Collapse Curve	124
D.10 Parameters Used to Calculate Reference Curves at Elevated Temperature	125
D.11 Calculation of Scaling Factor for Reference Curves at Elevated Temperature	125
D.12 Parameters Used to Calculate Reference Curves	129
D.13 80 % CEE ^a Points and TLE ^a Load Points at Ambient Temperature	132
D.14 Potential LP 22 _a 95 TLE ^a Load Points Based on Curve 3 ^a , Curve 4 ^a , and Curve 5 ^a	134
D.15 Potential LP 26 _a 95 TLE ^a Load Points Based on Curve 3 ^a , Curve 4 ^a , and Curve 5 ^a	134
D.16 95 % CEE ^a Points and TLE ^a Load Points at Ambient Temperature	135
D.17 Potential LP 22 _a 90 TLE ^a Load Points Based on Curve 3 ^a , Curve 4 ^a , and Curve 5 ^a	136
D.18 Potential LP 26 _a 90 TLE ^a Load Points Based on Curve 3 ^a , Curve 4 ^a , and Curve 5 ^a	136
D.19 90 % CEE ^a Points and TLE ^a Load Points at Ambient Temperature	137
D.20 TLE Load Point at 150 °F (65 °C)	139
D.21 Potential LP 22 _e TLE ^e Load Points Based on Curve 3 ^e , Curve 4 ^e , and Curve 5 ^e	140
D.22 Potential LP 26 _e TLE ^e Load Points Based on Curve 3 ^e , Curve 4 ^e , and Curve 5 ^e	140
D.23 90 % CEE ^e Points and TLE ^e Load Points at Elevated Temperature	141
D.24 Example Pipe Parameters Used to Calculate Load Schedules	142
D.25 TS-B 80 % Level at Ambient Temperature	145
D.26 TS-B 95 % Level at Ambient Temperature Without Bending	146
D.27 TS-B 90 % Level at Elevated Temperature with Bending	148
D.28 TS-B 90 % Level at Ambient Temperature with Bending	152
D.29 Example Pipe Parameters Used to Calculate Series C Load Schedules	155
D.30 CAL IV Series C Thermal Cycle Load Schedule	156
D.31 CAL IV Series C Mechanical Cycle Load Schedule	158
D.32 Example Pipe Parameters Used to Calculate Series A Load Schedules	159
D.33 TS-A 90 % Level at Elevated Temperature (QI, QII)	160
D.34 TS-A 90 % Level at Elevated Temperature (QIII, QIV) and (QIV, QIII)	162
D.35 TS-A 90 % Level at Elevated Temperature (QII, QI)	163
D.36 TS-A 95 % Level 5 QI-QIII Cycles	165
D.37 TS-A 90 % Level at Ambient Temperature (QI, QII)	167
D.38 TS-A 90 % Level at Ambient Temperature (QIII, QIV) and (QIV, QIII)	169
D.39 TS-A 90 % Level at Ambient Temperature (QII, QI)	170
D.40 TS-A 95 % Level at Ambient Temperature (QI, QII)	172
D.41 TS-A 95 % Level at Ambient Temperature (QIII, QIV) and (QIV, QIII)	173
D.42 TS-A 95 % Level at Ambient Temperature (QII, QI)	175
D.43 Example Pipe Parameters used to Calculate Reference Curves at Ambient Temperature	176
D.44 CEE ^a Points and TLE ^a Load Points	177
D.45 Example Pipe Parameters Used to Calculate Reference Curves at Ambient Temperature	179

Contents

	Page
D.46 Nominal CEE	180
D.47 Actual CEE	181
E.1 Typical Results from Frame Load Range Determination (100 kN to 2000 kN)	182
F.1 Sizes to Be Full-scale Tested to Satisfy the Schematic Shown in Figure F.1	188

Currently in preview, click buy full version

Introduction

This recommended practice (RP) is part of a process to provide reliable threaded tubing and casing connections fit for purpose for the oil and natural gas industry. It has been developed based on improvements to API RP 5C5, Third Edition, with input from leading users, manufacturers, and testing consultants from around the world. This RP represents the knowledge of many years of testing experience.

The validation of the connection test load envelope and failure limit loads is relevant to design of tubing and casing for the oil and natural gas industries. Tubing and casing are subject to loads that include internal pressure, external pressure, axial tension, axial compression, bending, torsion, transverse forces, and temperature changes. The magnitude and combination of these loads result in various pipe body and connection failure modes. Connection failure modes and loads are generally different and often less than that of the pipe. Consequently, experimental validation is recommended when previous testing/analytical information and sufficient field experience are not available to provide confidence in the use of the connection. The user is responsible for appropriate interpretation of the test data and determination of the user's minimum connection performance envelope.

When evaluating a connection performance envelope, it is necessary to consider the possible range of performance parameters and to apply test and limit loads under conditions targeting the extremes of those parameters. Testing at the extremes of the performance parameters assures that the production population that falls within these limits meets or exceeds the performance of the test population. Variables that contribute to threaded connection performance include dimensional tolerances, mechanical properties, surface treatment, makeup torque, and the type and amount of thread compound. For typical proprietary connections, worst-case dimensional tolerances are assumed and defined in this RP. For other connection designs, analysis may be required to define worst-case tolerance combinations.

It is necessary that users of this RP be aware that further or differing requirements might be needed for individual applications. This RP is not intended to inhibit a vendor from offering, or a purchaser from accepting, alternate equipment or engineering solutions for an individual application. This is particularly applicable when there is innovative or developing technology. Where an alternative is offered, it is the responsibility of the vendor to identify any variations from this RP and to provide details.

For specific applications that are not evaluated by the tests herein, supplementary tests may be appropriate. Annex G describes some examples of special applications where supplementary testing may be considered. The user and manufacturer should discuss well application and the potential limitations of the connection under consideration.

Representatives of users and/or other third-party personnel are encouraged to monitor the tests.

Procedures for Testing Casing and Tubing Connections

1 Scope

This Recommended Practice (RP) defines tests to determine the galling tendency, sealing performance, and structural integrity of threaded casing and tubing connections. The words “casing” and “tubing” apply to the service application and not to the diameter of the pipe. This RP addresses the primary loads to which casing and tubing strings are subjected: fluid pressure (internal and/or external), axial force (tension and/or compression), bending (buckling and/or wellbore deviation), and temperature variations.

2 Normative References

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

API Specification 5CRA, *Specification for Corrosion-resistant Alloy Seamless Tubes for Use as Casing, Tubing and Coupling Stock*

API Specification 5CT, *Specification for Casing and Tubing*

API Technical Report 5C3, *Technical Report on Equations and Calculations for Casing, Tubing, and Line Pipe Used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing*

API Specification 5L, *Specification for Line Pipe*

ASTM A370 ¹, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

3 Terms, Definitions, Symbols, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1.1

actual API collapse curve at ambient temperature

Derived for the test specimen from API 5C3 using measured maximum average outside diameter (OD), measured minimum average wall, and measured minimum ambient temperature material yield strength as input parameters.

NOTE For the reference to API 5C3, the appropriate section that applies addresses the *external pressure resistance*.

3.1.2

actual VME curve at ambient temperature

Derived for the test specimen from API 5C3 using measured maximum average OD, measured minimum wall (for hoop stress only), measured minimum average wall, and measured minimum ambient temperature material yield strength as input parameters.

NOTE For the reference to API 5C3, the appropriate section that applies addresses the *triaxial yield of pipe body*.

3.1.3

ambient temperature

Actual current temperature of the test lab environment at the time of testing.

¹ ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.